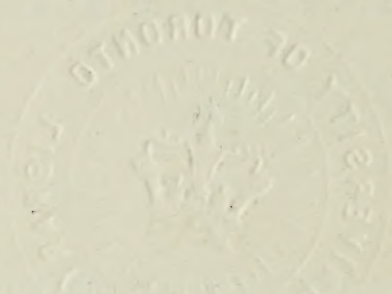# THE IRON AND STEEL MAGAZINE

SUCCESSOR TO THE METALLOGRAPHIST

A MONTHLY PUBLICATION DEVOTED TO THE
IRON AND STEEL INDUSTRY

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IRON MANUFACTURE IN MEXICO *

By JOHN BIRKINBINE

THE mineral wealth of Mexico is the theme upon which many pages have been written, but the bulk of this discussion refers to the production of the precious metals, for Mexico has been considered especially as a silver country. G a u g e d, however, by the known deposits of the baser u s e f u l minerals, the republic should also achieve importance in diversified manufactures.
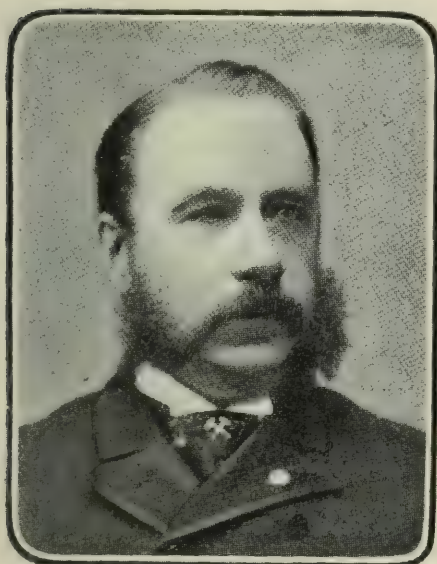
The republic has some phenomenal deposits of iron ore, but up to the present time the utilization of these has been on moderate scale, and while the production and manufacture of iron and steel may be expected to grow, such growth will probably be gradual, for the dream of enormous developments does not seem warranted from existing conditions.

The topographical features may be summarized as a great central plain, elevated from three to eight thousand feet above sea level, defined by rugged Sierras and separated on one side

*Received December 26, 1905.

from the Gulf of Mexico, and on the other from the Pacific Ocean, by relatively narrow strips of "terra caliente." The bulk of the population reside upon the great plateau, which itself is broken by spurs from the main Sierras and by independent mountains.

The railroad development, which now approximates 12,000 miles, is mainly on the central plateau, and the only complete connection between the Gulf of Mexico and the Pacific Ocean is by the Tehuantepec Railroad. The eastern Sierras have been overcome by two lines of railroad from Tampico; one to Monterey, and the other to San Luis Potosi, connecting with the general railroad systems at these points. Two railroads also overcome the mountain obstruction between Vera Cruz and the city of Mexico. Although numerous surveys have been made, and several routes projected, there is, at present, no direct railroad communication between the great plateau and the Pacific Ocean.

In one essential for iron and steel manufacture, viz., an abundance of fuel, Mexico is deficient. Important deposits of tertiary coal are wrought in northeastern Mexico, the product of the mines being used as coal and also converted into coke of fair quality. Good coal deposits exist in the state of Sonora, between the western Sierras and the Gulf of California, and other deposits are reported in Guerrero and Oaxaca in southern Mexico, on the southern or western slope of the Sierras. The distance of the coal deposits in northeastern Mexico from the capital is such that the price of this fuel is regulated by European or American coals, brought to Gulf ports by vessels and carried by railroad over steep grades, passing over summits 8,000 feet or more above sea level.

Some historians claim that the great plateau of Mexico was formerly well timbered, asserting that the demands for lumber and fuel for hundreds of years, and wasteful cutting, has denuded this territory. To-day the plateau is nearly barren of tree growth, the few scattered patches of mesquite or huisachie, upon the plains, and cottonwood, live oaks or pepper-tree fringing the few perennial streams, are the only evidences of arboreal life, if we except the pithy bayonet and nopal (or prickly pear) which grow to tree size. On the Sierras there is considerable forest growth of resinous and hard woods, especially where distance or difficulty of transportation has interfered with denudation.

Another feature of Mexican topography is the limited

number of streams which traverse or appear upon the plateau. A restricted rainfall, unevenly distributed, causes months of drought which may be followed by abnormal local precipitations cutting the plateau by numerous arroyos and barancas in which most of the year no water flows, while for limited intervals they are swept by raging torrents.

The great mass of the population of Mexico may be classed as peons, earning to-day from one tenth to one fourth of the average of a laborer in the United States; consequently, their wants are few, and until conditions improve (and they are improving), the average per capita requirement of iron and steel products cannot be expected to compare with those of the United States, or of other countries where industrial development has been more marked.

The fact above mentioned, that Mexico has 12,000 miles of railroads, may be considered as favoring the rapid extension of iron and steel industries; but to encourage these railroads the Mexican government admitted free, or allowed most liberal customs rebate upon all materials used in construction or maintenance of these roads. This same policy is still in force and may be expected to continue until the industrial development is such as to satisfy the government that, with moderate protection, Mexico can produce iron and steel in various forms.

The republic is now making some of its pig iron and steel and iron manufactures, but the aggregate of these is a small factor in the total consumption. A half dozen charcoal blast furnaces, located in or near to the Sierras, produce pig iron, castings, bar iron, etc., and a modern blast furnace and steel plant has, in late years, been erected at Monterey. The plant at Monterey uses coke as a blast-furnace fuel, and the works at Durango has employed both charcoal and coke, but is mainly dependent upon vegetable fuel. Although the number of plants is small, the range of design, equipment and operation varies from the primitive cold-blast charcoal furnace fed with fuel, ore and flux, brought to it on the backs of mules, to an iron-shell furnace, with fire-brick stoves and improved appliances. Similarly, the rolling mills include a small train driven by a water wheel, manipulating metal which has been puddled with kiln dried wood, to a powerful composite train, arranged to produce railroad bars or structural shapes from billets heated by producer gas,

and ingots cast from 35-ton open-hearth steel furnaces.   To the latter plant the materials are conveyed, and from it the manufactured products are carried by railroad.

In view of the foregoing statement, the question arises whether Mexico was ready for as pretentious an enterprise as was started at Monterey.   There is a large amount of iron ore in northern Mexico which is available; the possibilities of obtaining fuel are also good, but the fact that this enterprise imported coke from the United States has been used to discredit the local supply, or to demonstrate that the plant was in advance of requirements.

Ranking second in size to the Monterey plant is that of Durango, which consists of a blast furnace, rolling mill, foundry and machine shop, located at the foot of the Cerro de Mercado, which to all appearances is truly entitled to being designated a " mountain of iron ore."

The plant has command of enormous reserves of mineral rich in iron, and while it has at times used coke, charcoal seems to be the natural fuel which late railroad extensions, and others projected, should apply to it in liberal quantities at fair prices. It also has direct connection with the railroad system of Mexico, but like many such enterprises has been handicapped by extravagant capitalization and errors of early management.

It is not the wish of the writer that this contribution should be considered as pessimistic.   It has been his privilege to make several extended trips in Mexico to study the possibilities of iron and steel manufactures.

The first of these was made in 1882, in advance of railroad construction, when the country was viewed as it had been for hundreds of years, peons plowing with sharpened sticks in the shadow of one of the most remarkable deposits of iron ore; mules hauling wheeled vehicles made entirely of wood and of which metal formed no part whatever; water drawn from wells by earthen vessels attached to ropes or thongs, the mechanism operated by oxen and whim; and smelters fed by hand, the fire being intensified by large bellows operated by man-power.   All the labor required was then obtained for 25 centavos per day; and boxes to convey samples from the Cerro de Mercado were made dovetailed, because the carpenter wage for such work was less than the cost of the nails required.

In subsequent visits he traversed, in Pullman cars, territory in an hour, over which he formerly lumbered for a day in diligencias. He has seen the American plow and other American agricultural implements, the American wagon, barbed wire and many European manufactures sold in large quantities. Steam pumps have replaced the primitive appliances, and modern smelters are located so as to receive and ship their supplies by railroad. The wage rate has advanced and is seldom below 50 centavos per day; in many cases it is 75 centavos to one peso, one dollar, in Mexican money, while mechanics earn from 2 to 5 dollars per day in Mexican money.

The stocks carried by some of the Mexican hardware firms compare favorably with those in large American cities, but nearly all these goods are imported and command what we would consider fancy prices, while on market days in any Mexican city, junk dealers are found with their wares spread out on the pavement, consisting of old nails, spikes, pieces of bar iron, locks, hinges, keys, in fact anything which is of metal, and for all of which there appears to be a demand.

In 1882, nails cost, in Durango, 35 centavos per pound; in 1905, wire nails were quoted at 13 dollars and cut nails at 15 dollars (Mexican) per keg. At the rolling mill at the Tunal River, in 1882, bar iron demanded from 15 to 19 centavos per pound, according to size; in 1905, similar iron sold at retail from 6 to 8 centavos per pound. In the above the relative value of Mexican and American money may be equated as two to one.

These facts apparently indicate a good demand for iron and steel products, and the writer believes that Mexico should soon be producing a large portion of these. Mills and factories are multiplying, and the harnessing of some of the water-powers will increase the number of industrial enterprises. Capital in large amounts is invested in mines and in smelters, so that, independent of the railroad demands, there is much to encourage those interested in the production of iron and steel.

Improved conditions for the people, due to advanced rates for labor, and the facilities which the roailroad extensions offer for bringing portions of the country into communication, are factors which must be considered in discussing the problems of iron and steel manufacture in Mexico.

The writer, however, is impressed with the possibilities of

failure in attempts to anticipate too rapidly the future of the republic.   In the United States there have been but few successes and a number of failures reported, where comprehensive iron and steel industries were located at new points.   The development of ore and fuel supplies in sufficient volume to support a large plant is not accomplished in months, neither will a few thousand tons of ore, gained from shallow workings, prove the volume, character or the future dependence of an ore deposit. The labor element alone may make or break an enterprise.   If local labor is used it must be educated at the cost of numerous failures and many deficiencies.   If skilled labor is brought from a distance it is apt to be of the peripatetic class which is seldom satisfied and seldom satisfies the employer; but if, owing to extravagant wage rates and other inducements, good labor is obtained, few reliable men will agree to leave permanently a locality where they and their families are contented with surroundings and associates.

Owing to the limited opportunities afforded to Mexicans to become acquainted with the metallurgy and practice of iron and steel manufacture, it is probable that foreign supervision will be essential for success; but it is equally probable that the plant which gives the best results will depend largely on Mexican labor.

Notwithstanding the many criticisms concerning Mexican labor, the number of fiestas observed and the lassitude, due to the residence in the torrid and semi-torrid zones, practical experience has demonstrated that Mexican labor is good, fairly reliable and imitative.   The natives are capable of serious and long-continued exertion, which is demonstrated by the dog-trot which peons affect when loaded down with two long timbers carried by harness from the shoulders, or when climbing the steep trails, carrying on their backs from 100 to 150 pounds of wood, charcoal, ores, dirt, etc.

At the wage rate which formerly prevailed, the Mexican peon had little incentive for advancement.   Under improved conditions he is more comfortable, and owing to more liberal education new aspirations arise.   The average peon is fond of gambling, cock-fighting and of liberal indulgence in mescal, but he is quick to imitate, and must be held under rigid discipline. At Durango an imported rolling-mill force has been entirely dis-

placed by Mexicans, and elsewhere I have seen their proficiency at furnace, mill and foundry.

The conditions, as described, the writer interprets as encouraging the moderate establishment of new, and the extension of existing, iron and steel industries, and have them grow with the country.

BLAST-FURNACE CALCULATIONS *

By J. L. STEVENSON

IN commencing to design a new blast-furnace plant, the first question to decide is the output capacity of the furnace it is intended to construct, dependent to a certain extent upon the available material it is proposed to use in the smelting. The output capacity having been decided upon, say, for a make of 260 tons per day, from material which we will suppose to be iron ore containing 45 to 50 per cent metallic iron, and giving an analysis of the following composition or nearly, with coke as fuel, with, if possible, in the composition shown in the table of coke analysis. The number and size of engines, and the size and number of steam boilers, may at once be decided upon, so as to complete the general plan. The furnace, then, is to smelt iron ore containing 45 to 50 per cent metallic iron and have coke as fuel, with limestone as the fluxing agent.

ANALYSIS OF ORES

		1	2	3
		Per cent	Per cent	Per cent
Fe_2O_3	Peroxide of iron............	71.03	75.28	69.64
FeO	Protoxide of iron............	.28	—	—
MnO_3	Peroxide of manganese......	—	Trace	3.64
MnO	Protoxide of manganese.....	—	—	—
Al_2O_3	Alumina....................	1.52	—	—
CaO	Lime......................	.45	Trace	2.85
MgO	Magnesia..................	—	—	—
SiO_2	Silica.....................	6.65	14.80	5.10
P_2O_5	Phosphoric acid............	.04	Trace	.012
SO_3.	Sulphuric acid.............	—	—	—
TiO_2	Titanic acid...............	—	—	—
H_2O	Water combined............	8.83	—	—
H_2O	Water hygroscopic..........	9.10	3.30	8.00
Cu......	Copper....................	—	.09	—
S.......	Sulphur...................	.05	.34	.06
Fe......	Metallic iron..............	49.72	52.70	48.75

* " The Engineer," August 25, 1905.

ANALYSIS OF COKES

	I	2	3
	Per cent	Per cent	Per cent
C..........................	91.77	91.99	93.05
S.........................	.72	.80	.55
H₂O	.40	.80	.23
Ash.......................	6.94	5.67	6.17
Volatile matter..........	.17	.74	—
	100.00	100.00	100.00

We will now give the methods by which to arrive at the shape and size of the furnace and the necessary intimate equipment for the production of the output decided upon. A 260-ton furnace has been selected to illustrate more readily the means of arriving at the size, shape and equipment, as it is a standard size. A furnace for a make of 260 tons per 24 hours should be 80 feet high from hearth to platform, and have a bosh of 18 feet diameter. It must at once be pointed out that the rules about to be given are not applicable to furnaces the dimensions of which are not in proportion to each other, and also that although a furnace may have a bosh in proportion to its height, the output shown by these rules will not be obtained in practice unless the furnace when working shall be equipped and supplied with the other requirements necessary and defined for that make. Let the reader divest his mind of the old practice of improving the lines of a furnace, without either increasing the blast to the required volume or the stove-heating surface in hope of better result, a practice which has been carried out for years in most works without resultant improvements. The rule for finding the working capacity of a furnace when the sizes are given is as follows:

Square the diameter of the bosh in feet, multiply by the total height of the furnace in feet and divide by one hundred. This will give the nominal make per 24 hours for that size of furnace, provided the furnace equipments are in accordance with the other rules given; so that the formula for a properly proportioned and equipped furnace will be as follows:

$$\frac{B^2 \times H}{100} = \text{make in tons per day.}$$

Where   B = bosh diameter.

               H = total height of furnace.

Therefore, the 260-ton furnace which we are now working out will give:

$$\frac{18^2 \times 80}{100} = 259.20 \text{ tons per day} - \text{say, 260 tons.}$$

This shows that 80 feet is the proper height of the furnace and that 18 feet is the right diameter of the bosh for that make,
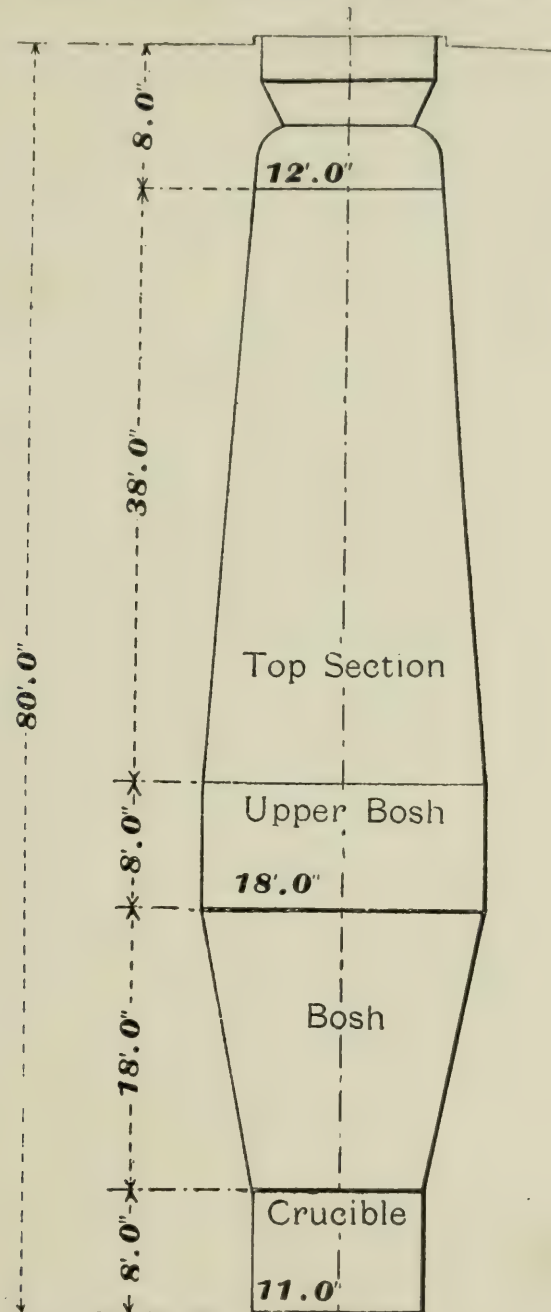
Section of 18-foot × 80-foot Furnace

[This furnace section is to illustrate contents calculations.]

according to the method of calculating the output capacity, which has always proved correct.   As an example, we will take a smaller furnace of 93 tons output per day of 24 hours.   This small furnace has a total height of 55 feet, a bosh of 13 feet diameter and will work out as under:

$$\frac{13^2 \times 55}{100} = 92.95 \text{ tons per day} - \text{say, } 93.00 \text{ tons.}$$

Let us now take as a further illustration a larger furnace, having a bosh of 22 feet diameter and a total height of 100 feet. These dimensions will work out as follows:

$$\frac{22^2 \times 100}{100} = 484 \text{ tons per day.}$$

Top Section
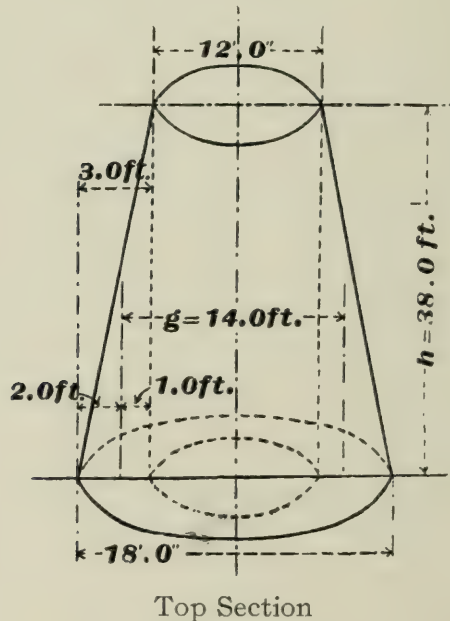
It is often necessary to ascertain the burden capacity of a blast furnace, not because of the old idea that a large cubical capacity has the greatest output, but because it is always useful to know the weight of the contents of a furnace for many purposes, and we will give two methods adopted in working out the contents capacity:

Volume by Pappus' Theorem

$V = \pi g A$, where
V = volume; g = radius of circle described by center of gravity $\times 2$ = diameter.
A = area of figure.

$$A = \frac{3.0 \times 38}{2} = 57.0 \text{ square feet.}$$

Cylinder, D = 12 feet; area = 113.0; N = 38 feet.
Volume = 113 feet × 38 feet = ... 4,294.00
Triangular figure:
  g = 14 feet; circumference = 43.93.
  Area of triangle = 57.0.
  3.1416 × 14 × 57 = ... 2,506.99

    Total cubic feet....................... 6,800.99
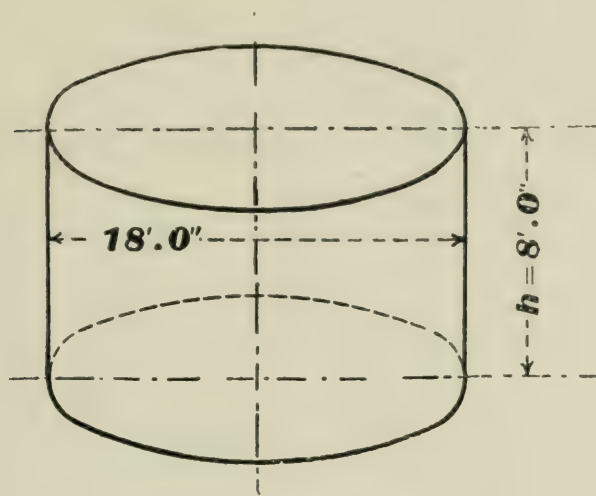
Upper Bosh Section

Cylinder, D = 18 feet.
Area = 254.46.
h = 8 feet.
V = A × h = ... 2,035.60

V = πgA, where
V = volume.
g = radius of circle described by center of gravity × 2 = diameter.
A, area of figure.
$$A = \frac{3.5 \times 18}{2} \text{ feet} = 31.5 \text{ square feet.}$$

Cylinder, D = 11 feet; area = 95.03.
Volume = 99.03 × 18 feet = ... 1,710.54
Triangular figure:
  g = 13.34 feet; circumference = 43.98.
  Area of triangle = 31.50.
  3.1416 × 13.34 × 31.50 = ... 1,319.85

    Total cubic feet in frustum.................. 3,030.39

[The frustums are exaggerated to facilitate illustration.]

Cylinder, D=11 feet.
Area=95.03.
h=8 feet.
V = A×h= . . . . .cubic feet   760.24
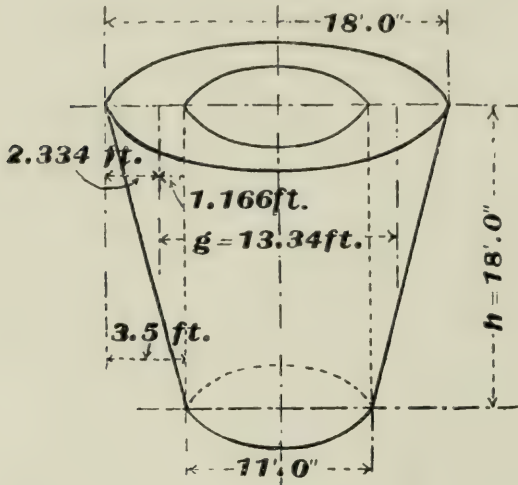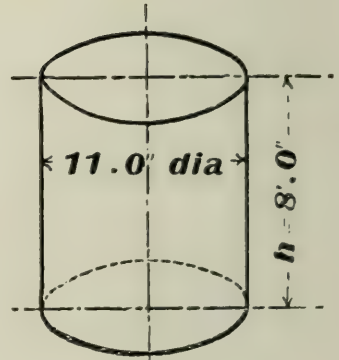
Bosh Section   Crucible

TOTAL VOLUME OF FURNACE

Top section.	6,800.99
Upper bosh	2,035.60
Bosh.	3,030.39
Crucible.	760.24
Cube feet.	12,627.22

The output capacity of this furnace being 260 tons per day gives 48.56 cubic feet of contents per ton of iron per 24 hours.

Having now shown the method of ascertaining the capacity of a blast furnace, both as regards output and contents, it is necessary to say that experience and experiments have proved that furnaces of a certain size and shape give the best results when supplied with a certain volume of air, certain stove power, certain pressure for penetration, certain tuyère area and so on, each requisite for the make for which any particular furnace was intended for.   It was then that rules were worked out, and those were adopted which gave the best results, and which have proved correct and indispensable in the designing of blast furnaces. The writer has endeavored to put those rules before his reader

in such a form as to make them intelligible and useful to all interested in blast furnaces and blast-furnace work.

Working still on the 260-ton furnace, we will suppose that the engineer who is intrusted with the designing and construction of the plant has no further information given him than that a furnace is required to produce 260 tons, or any other quantity, per day, from iron ores containing from 45 to 50 per cent of iron. The first rule to make use of in this case is the following, because, the make required being known, we must obtain from it what the size of the furnace should be. Thus:

$$\sqrt[3]{M} \times 2.85 = B.$$

Where
M = make of iron per day,
B = diameter of bosh in feet.
2.85 is a constant.

In working out this formula for the furnace we are dealing with, we obtain:

$$\sqrt[3]{260} = 6.382 \times 2.85 = 18.18 \text{ feet diameter — say, 18 feet.}$$

Having thus ascertained that the bosh should be 18 feet diameter, we proceed to obtain the proper height of the furnace for the above output, and for that purpose make use of the following formula:

$$H = \sqrt[3]{M} \times 12.5.$$

Where
M = make of iron per day.
H = total height of furnace.
12.5 is a constant.

Thus, in working out this rule we obtain

$$\sqrt[3]{260} = 6.382 \times 12.5 = 79.77 \text{ feet — say, 80 feet high.}$$

Having now obtained the main dimensions of the furnace, we check them by the use of the formula given earlier,

$$\frac{B^2 \times H}{100} = M.$$

Which works out as follows:

$$\frac{18^2 \times 80}{100} = 259.20 \text{ tons — say, 260 tons.}$$

A furnace with a bosh 18 feet diameter may be only 75 feet high, and have a good output under the same outfit conditions, but there would be more loss of heat, which would mean greater cost in fuel during the year.

Having decided upon the output and having worked out the size of the bosh and the height of the furnace, we must now know what hearth diameter such a furnace will require before we can decide upon the number and size of tuyères. In a furnace of this size the blast power must be considered in determining the size of hearth, and as a few inches extra diameter are no detriment, we will adhere to the rule given in deciding as to the size of the hearth for this furnace. Here we have:

$$\sqrt[3]{260} \times 1.80 = \text{hearth diameter.}$$

Where the cube root of make in tons, multiplied by the constant 1.80, gives the diameter of the hearth. Therefore,

$6.382 \times 1.80 = 11.487$ feet diameter — say, 11 feet 6 inches diameter.

As the furnace will produce when in full working order between 10 and 12 tons an hour, we must see what is the height

By Method of Conical Frusta

$$V = (d^2 + dD + D^2)\frac{.7854h}{3}. \quad \text{Where} \begin{cases} d = \text{Small diameter} \\ D = \text{Large} \quad\quad ,, \\ h = \text{Height} \end{cases} \text{of each frustum.}$$

DIMENSIONS ALL IN FEET

Part	d	D	dD	d^2	D^2	d^2+D^2	d^2+dD+D^2	h	$\frac{.7854\,h}{3}$	Volume in Cube Feet
Top	12	18	216.0	144.0	324.0	468.0	684.00	38.0	9.94	6,798.96
Upper bosh....	—	18	—	—	—	—	—	8.0	—	2,035.68
Bosh	11.0	18	198.0	121.0	324.0	445.0	643.00	18.0	4.71	3,028.53
Crucible.......	—	11	—	—	—	—	—	8.0	—	760.24
Total cube feet .	..	..	..	..	..	..	..	..	..	12,623.41

By first method................... 12,627.22
By second method................... 12,623.41

2) 25,250.63
Average =   12,625.315

the metal will rise to in the crucible in six hours, so as to determine the distance from hearth level to the slag outlet. We will take the diameter of the hearth at 11 feet 6 inches, which gives an area of 103.86 square feet. The production being at the rate of nearly 11 tons an hour, this will mean 6½ inches deep in the

crucible per hour, and 3 feet 3 inches deep in 6 hours, so we will take this as the maximum weight for two reasons: first, because 11 tons is a little in excess of the actual make; and, secondly, because the crucible is taken as new. So we will allow above the 3 feet 3 inches, 12 inches from top of the iron bath in the crucible to the center of the slag outlet, making a total distance of 4 feet 3 inches from hearth level to the center of the slag notch. To avoid serious troubles it is advisable, and will be found beneficial, when the iron is not taken away for steel making, to cast every four hours from this size furnace to avoid the pressure against the walls of the crucible becoming excessive by too great a depth of metal, which is apt to cause very serious and costly breakouts. The position of the slag outlet being known, the center of the tuyères must be placed 2 feet above center of slag notch, giving a height of 6 feet 3 inches from hearth level to center of tuyères. In this case the standing round the furnace may be raised 2 feet above the hearth, thus bringing the tuyères within easy working reach of 4 feet 3 inches above the standing.

The next question which requires attention is the number and size of tuyères necessary to insure proper distribution of the blast, and the right tuyère area requisite per ton of make intended. The tuyère area required for the well-doing of a furnace is $1\frac{1}{4}$ square inches per ton of iron per 24 hours. So that for a 260-ton furnace we require $260 \times 1.25 = 325$ square inches total area, and as the furnace will take 10 tuyères, then:

$$325 \div 10 = 32.5 \text{ square inches per tuyère.}$$

This will mean ten $6\frac{1}{2}$-inch tuyères, each tuyère being equal to a capacity of 26 tons, or

$$325 \div 8 = 40.6 \text{ square inches per tuyère,}$$

which would give 8 tuyères of a little over 7-inch diameter; 7-inch tuyères in this case would give a little extra pressure by the reduction of area, but ten $6\frac{1}{2}$-inch tuyères would be preferable as being the right area for a 260-ton furnace. If a tuyère is not placed over the tapping hole, nine tuyères only would be used, but this is not advised, as they should be distributed round the furnace as regularly as possible, placing one over or near the slag hole and one over the tapping hole. A diameter of hearth

11 feet 6 inches will give about 3 feet 6 inches center to center of tuyères inside the furnace and 5 foot centers outside the brick-work of the crucible, which is ample for all purposes.

We will now deal with the stove power required for the output named, viz., 260 tons per day. When a furnace is equipped with fire-brick stoves, the heating surface required per furnace is 444 square feet per ton of iron that the furnace is intended to produce in 24 hours, so that the furnace we are now working out will require $260 \times 444 = 115,440$ square feet.

This heating surface when divided into four stoves gives 28,860 square feet per stove. A 20×60 stove contains 30,158 square feet of heating surface, which is equal to a duty capacity of 68 tons. Thus, $68 \times 4 = 272$ tons, giving a capacity slightly in excess of the power actually required. Therefore, we shall need for this furnace four stoves 20 feet diameter, 60 feet high, each having a heating surface of not less than 30,000 square feet, and equal collectively to 270 tons per day, and so on in proportion for a lesser or larger make.

As there should always be two stoves on blast at a time to each furnace, we have an available contact surface for blast of over 60,000 square feet continually in action.

The amount of blast required for any make of iron is 140 cubic feet of free air per minute per ton of iron per 24 hours. So that the furnace now under consideration will require $260 \times 140 = 36,400$ cubic feet of air per minute.

Three engines of the following dimensions will give a little in excess of the amount of air actually required for the output: Steam cylinder, 42-inch diameter; air cylinder, 84-inch diameter; stroke, 48 inches; revolutions, 40. The amount of free air delivered per minute by each engine $= 12,313$ cubic feet. The duty capacity of each engine is 87 tons at 40 revolutions. So that $12,313 \times 3$ engines $= 36,939$ cubic feet per minute collectively, which gives a few revolutions to spare in case of need.

Before leaving this subject attention should be called to the advantages of a circular main round the furnace instead of a horseshoe main, especially where the connection to the hot-blast main is not central, in which case, with a horseshoe main, the pressure and heat at each tuyère will be somewhat different, and the furnace will work one-sided. The blast should have a free circulation all around the furnace.

The following section and quantities are worked out from the formulæ in the text in order to illustrate the calculations given.
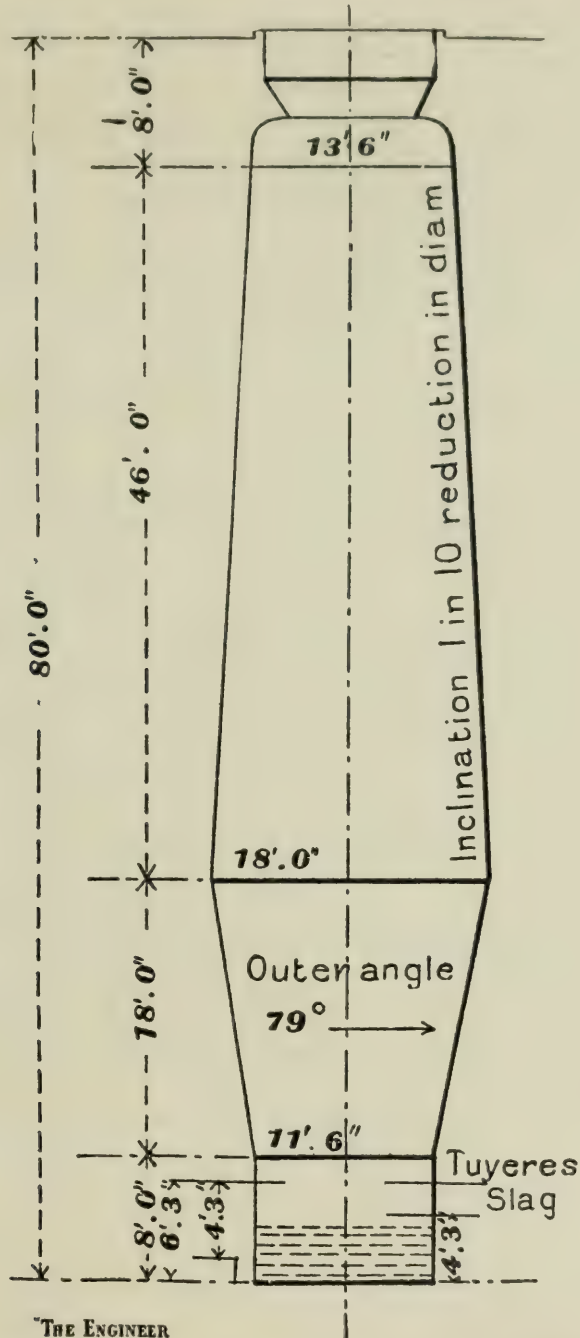
Section of 18-foot × 80-foot Furnace of 260 Tons

Power required: Blast, 36,400 cubic feet per minute; heating surface, 115,440 square feet; tuyère area, 325 square inches.

As this article is intended as much for students as for experienced men, the very urgent necessity of using every appliance and making every effort to maintain the heat of the blast at an even temperature cannot be too much impressed upon the readers. Nothing is more detrimental to the even quality of products than variations in blast temperature; it not only changes the quality of the iron produced, but causes great changes in the quantity of iron output. It must, nevertheless, be said that it is often absolutely necessary to increase the temperature and capacity of the blast in order to raise the heat in the furnace. By this means a threatened scaffolding may be avoided. This should not be done by merely turning on a freshly heated stove, the excessive heat of which only lasts a comparatively short time, but by equipping the furnace with self-acting and properly designed apparatus, which will allow the heat to be regulated to any point between 1000 degrees and 1400 degrees, according to the number of stoves supplying the heat, but equalizers do not permit of this regulation to any requisite temperature, and the furnace has to take the blast at whatever heat the apparatus will give it. A furnace will work considerably hotter during the time the crucible is full of molten metal than immediately after a cast.

SUMMARY OF POWER REQUIRED FOR ANY OUTPUT PER FURNACE

Blowing Engines. — For every ton of iron intended to be produced per 24 hours allow 140 cubic feet of free air per minute per furnace coke practice. Charcoal, 110 cubic feet; anthracite, 150 cubic feet.

Stoves. — 444 square feet of heating surface per ton of iron per 24 hours.

Tuyères. — 1¼ square inches per ton of iron per 24 hours per furnace.

THE MANUFACTURE OF FORGINGS *

By FRANK SOMERS

ONE of the first tools used to save human labor in the manufacture of iron forgings was the helve. Then came the tilt hammer, which was quicker in action. They are both still used for certain classes of work, and are very economical where water-power is available. However, for treating large masses of metal, both, in many ways, are inefficient instruments. In the first place, since the head of the hammer on the helve or tilt is really moving in the arc of a circle, it is incapable of giving a flat blow to a large piece of work; the portion of metal which is near the hinge, about which the helve or tilt turns, is unduly compressed, whilst that which is the farthest away from it receives scarcely any blow. It was also found not practicable to control the magnitude of the blow, which is always of the same magnitude.

These circumstances led to the invention of the single-acting steam hammer, by Mr. James Nasmyth, in 1842, by which invention forgings of a much larger size were enabled to be made. Mr. Nasmyth afterwards made the double-acting steam hammer, which is the most suitable piece of machinery both for the shingling of puddled balls and afterwards for the making of iron forgings from the puddled bars. It is quick in action, and when two pieces of iron are put under the hammer to be welded together, one or two sharp blows will weld them, and at the same time will do the iron a great deal of good by expelling a certain amount of slag from the metal. The steam hammer gradually became the universal tool for the manufacture of iron forgings and to-day is still the best tool for this purpose.

In the year 1856, Bessemer gave a description of his process for the manufacture of steel, but it was not for several years after that manufacturers extensively began to use steel made by his process. Gradually, however, more and more steel came to be used, and with steel produced by the open-hearth process in 1861, iron for the first time was rivaled for structural purposes.

As larger steel furnaces were built, larger ingots were produced and larger steam hammers were required to forge the

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* Read before the Staffordshire Iron and Steel Institute at Dudley, December 9, 1905.

ingots down to the required shapes. With very large steam hammers, the wear and tear and cost of upkeep is very great. You reach the maximum with a steam hammer for economical working when you get to about 12-ton size.

With a hammer of this size you can work on ingots up to about 20 tons weight, but when working on an ingot near this weight there is a great deal of vibration caused by the heavy blow needed in cogging the ingot down. This vibration caused a lot of breakages to the hammer, the cranes and the roof supporting the cranes. Hammers larger than the 12-ton size have been tried for the making of very large forgings, but, generally speaking, they were failures, due to the tremendous jar given by the blow.

The largest steam hammer ever built, I believe, is the one built by the Bethlehem Steel Company in the United States. It is a 125-ton steam hammer. The steam cylinder is 76 inches inside diameter, the hammer has a stroke of nearly 20 feet and weight of metal in anvil blocks is 2,150 tons. Though the Americans beat us in the size of steam hammers, this one is a failure from a working point of view. However, they have turned it into use from an advertising point, and it is now shown to visitors as a curiosity.

In view of the proportionately increased cost in the working of a large steam hammer compared with a small one with regard to output, manufacturers looked out for a tool that would do the larger work quicker and better, and that would cost less in upkeep in proportion to the output.

The hydraulic press was tried for forging, but at first was not a great success owing to its slowness when planishing and finishing forgings. However, this slowness has been overcome, and to-day presses are made giving over 40 strokes a minute. There are several types of hydraulic presses:

1. Those working with water supplied direct from pumps at high pressure.

2. Those working off accumulators.

3. Those working off accumulators, but using a hydraulic intensifier for actual squeeze.

4. Those using steam for the adjusting movement and the steam intensifier for the actual squeeze.

5. Those using water from accumulators at low pressure

for the adjusting movements, and the steam intensifier for the actual squeeze.

Describing the different types briefly: In number one there is a loss of efficiency, through having to use water under high pressure for adjusting movements; also there is a great deal of wear and tear on the pumps when working direct. This type, and the following two, are slow in action. In the fourth type, known as the Breuter Schmacher, no pumping engines are used, and water from a tank under about 60 pounds per square inch pressure is used for all filling up. The lifting of the tool is done by steam cylinders, whilst for the actual squeeze a steam intensifier is used. In the fifth type all the adjusting movements are done by water pressure of about 750 pounds on the square inch, and a steam intensifier is used for the actual squeeze.

The last two types have many advantages over the others for forging purposes.

In the works with which I am connected, we have a forging press of the latter type capable of exerting a pressure of about 3,600 tons. It consists of a hydraulic press proper, and a direct-acting steam intensifier placed on the top. This system is known as that of Haniel and Lueg, and they are the sole manufacturers of this type.

The press proper comprises a bedplate fixed in the ground and firmly bolted down to foundations of such shape as to add to the strength of the press, and increase the resisting surface. Four strong columns connect this bedplate to the fixed crosshead. In the middle of the crosshead is placed the pressure cylinder. The large ram thereof is fastened to the movable crosshead. This movable crosshead is guided by the four columns, and is connected by the rods to the rams of the two counterpoise cylinders.

The intensifier consists of a steam cylinder, which is strongly mounted on the top of the fixed crosshead by means of an intermediate piece; this piece is so designed as to give free access to different parts. The piston rod serves as a hydraulic ram, and acts in the pressure cylinder. For reducing the height of the press, the large ram has a hole bored in it considerably larger than the rod, which is thus enabled to work within.

The secondary hydraulic power for this press is furnished by engines which pump water into an accumulator weighted to

give a pressure of about 750 pounds on the square inch, and a pressure of water from this source is constantly maintained in the pipes leading to the two counterpoise cylinders tending to lift the rams and the movable crosshead to which they are attached.

By admitting water from this source into the pressure cylinder — whose ram has an area considerably in excess of the combined effective areas of the rams — it overcomes the lifting power of the two smaller rams, and causes the crosshead to descend. The counterpoise cylinders are then communicating with the pressure cylinder, and the water which is displaced by them is combining with the water from the low-pressure main and flows into the pressure cylinder. When the crosshead is required to be lifted through any considerable distance, a valve is opened which permits the water in the pressure cylinder to escape, and the combined lifting powers of the counterpoise cylinders drive the water out of it, and the crosshead continues to rise until the flow of water from the cylinder is stopped by the closing of the valve. The movements described are only for lifting the ram and crosshead, and for lowering the same into position on the piece to be forged; and for these purposes ordinary low hydraulic pressure is used. When going to forge, the crosshead is lifted up for the ingot to be placed on the anvil, and is then lowered till the upper tool rests on the ingot. All this adjusting is done by means of low hydraulic pressure, but a far greater pressure is necessary to forge the ingot on the anvil. For this purpose the steam intensifier is brought into use in the following manner: The pressure of water in the cylinder under the ram, which is caused by the lifting power of the counterpoise cylinders forcing the ram into the cylinder, is sufficient to keep the steam piston at the upper end of its stroke. On admitting steam into the cylinder on the top of the piston, the rod is forced downwards, raising the pressure of the water in the pressure cylinder, thus causing the ram and crosshead to descend through a much less distance than the ram, but with a proportionally greater power. During this pressing stroke, which is usually from about 6 to 6½ inches, the counterpoise cylinders are closed against the low-pressure main by a self-acting retaining valve, and they then only communicate with the air vessels which are arranged in the rams. When the crosshead descends under the

action of the steam intensifier, the water from the counterpoise cylinders is driven into these air vessels, raising the pressure from 735 to 800 pounds per square inch. On exhausting the steam from the cylinder, the elasticity of the air in the air vessels lifts the upper tool promptly, so that when finishing or planishing forgings, as many as forty strokes and more a minute can be had.

The advantages an hydraulic press gives over rolling and hammering on large pieces of steel are numerous. For example, taking a steel bloom from which cranks, shafts, etc., are made, the effect of cogging a large ingot down under rolls tends to produce an ingot of the shape shown on the screen. This is caused by the rolls drawing the outsides of the ingot, whilst the middle of the ingot receives far less work. This is proved by taking tests from rolled blooms. A bloom cogged down from an ingot under an hydraulic press presents on the end exactly the opposite appearance to the rolled bloom. Instead of being concave, it is convex. This proves that the force exerted by the press penetrates right into the middle of the ingot and bloom.

The same thing applies to the steam hammer as to the rolls when forging very large ingots. The effect the hammer has on a very large piece is that the sharp blow given tends to spread the outside parts of the metal while not penetrating right into the middle of the ingot, as in the case of the press. For this reason ingots are better cogged down into blooms by an hydraulic press.

For making round shafts V-anvils are used. This produces equal pressure as nearly as possible right through the piece being forged. Another advantage that the hydraulic press has over the steam hammer in making large forgings is that far more work can be done at one heat, thus saving a number of different heats on one forging. I, myself, have seen a tail shaft, weighing over 17 tons, forged outright from an ingot at the one heat. The piece was under the press for three hours, and at the end of that time the forging was still at a good temperature.

The maximum pressure of our press is nearly 3,600 tons, and the intensified pressure in the cylinder acting on the ram when at full pressure is 7,400 pounds on square inch. To keep the packing from leaking, both on the ram and round the piston rod, good water has to be used, and as we go to some little trouble in preparing it, we take care to return all exhaust back to tanks and to waste as little as possible.

The press is served with electric travelers. We have a 30-ton traveler now at work, and a 60-ton traveler being made which we hope to have at work soon after Christmas. The furnaces for heating the large ingots are no small item. The largest furnace which we are now commencing to build has an inside area of 400 cubic feet. Of course, the heating of a large ingot in one of these furnaces is not such a quick matter as in the case of smaller pieces and furnaces. If a very large ingot was suddenly placed in a furnace which was at a high temperature, the ingot would be liable to crack, owing to the outside expanding through heating quickly, whilst the middle of the ingot would not be affected by the heat for some minutes later.

For this reason large ingots are better heated slowly and then well soaked through. The steam necessary for the steam intensifier, and also for driving the electric generating plant, is supplied at present by one Lancashire hand-fired boiler and one Netherton vertical tube boiler, fired by the waste heat from gas furnace.

We are putting down another Netherton vertical tube boiler, which will be fired by waste heat from the new furnace we are commencing to build.

These boilers are connected to a steam receiver, slightly larger in area than the steam cylinder of the intensifier. This receiver prevents a rush of steam from any one of the boilers, which might cause priming.

The boilers work at 120 pounds per square inch pressure, and are fed with softened, filtered and heated water. The heating in the softener is all done by exhaust steam from different engines.

The feed water from the softener is very nearly at boiling point. To cope with the increased output, due to our press, we have had to put down more large lathes and machinery, and to increase the speed and power of some of the other machinery by driving them by means of electric motors. After large forgings are made it is very necessary to anneal them, to allow of the readjustment of the different molecules which have been subjected to stress due to forging. For this purpose we put the forgings when finished into a special furnace, heat them up to about 900° C., let them remain at this heat for some time, and then allow them to cool down slowly in the furnace.

OPEN-HEARTH FURNACE COMPARISONS — II *

By A. D. WILLIAMS, Jr.

Consumption of Fuel. — In the Pittsburg district and elsewhere where natural gas is available, a number of open-hearth furnaces are operated with this fuel, but owing to distrust in regard to the permanency of the supply at profitable prices for this use, the furnaces are designed so that they can be altered to use producer gas with slight changes in the flues. In the Carnegie No. 3 open-hearth plant the gas is brought to each of the 50-ton furnaces by a 6-inch supply pipe, which branches to both ends of the hearth and there divides into two 4-inch pipes, which pass down on each side of the ports to the burners. The burners are located close to the bottom of the ports about $3\frac{1}{2}$ feet back from the hearth. The average fuel consumption using natural gas, including gas used for heating the ladles, is about 10,000 cubic feet per ton, ranging from about 7,000 to 13,000 cubic feet. The gas costs about 5 to 8 cents per 1,000 cubic feet and has a calorific value of from 900 to 1,000 British thermal units per cubic foot, or 8,000 to 8,900 calories per cubic meter.

A few furnaces are operated with coke oven gas, but the fuel generally used is producer gas, which in a few cases is enriched by the use of oil. Abroad a great many furnaces use oil and producer gas. The use of oil is advantageous where the coal is low in volatile hydrocarbons; in such cases the use of oil changes the blue flame of the gas to a luminous flame of great radiant heat. The writer is under the impression that one of the German steel works is using blast-furnace gas and oil in its open-hearth furnaces with success. The fuel consumption of furnaces using producer gas ranges up from 450 pounds of coal per ton of steel, in some cases running over 1,000 pounds. A great deal depends upon the quality of the coal and likewise upon the arrangement of the plant; in fact, plants melting similar stock and making the same grade of steel using the same kind of coal will attain widely differing fuel results, owing to the layout of the plant and the personal equation of the operators. Long flues are undesirable, as the gas has an opportunity to

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* The " Iron Age," December 7, 1905. The first article was printed in the *Iron and Steel Magazine* for December, 1905.

cool and deposit a portion of the volatile combustibles in the gas main, where they are a total loss.

Large Gas Mains Desirable. — The gas flue leading from the producers should be for a minimum of sufficient size to permit of a man passing through them, and suitable manholes should be placed at convenient points. Underground flues should have a wall a brick and a half thick, of red brick, laid in cement outside of the fire brick lining, and the lining of steel gas mains should be at least 6 inches thick. A large gas main has the advantage of permitting the gas from the different producers to mix, and in this way insures uniformity in the composition of the gas supply. It also acts as a reservoir or gas holder in smoothing off the peaks in the demand for gas by the furnaces to suit the production curve of the producers. In determining the size of the gas main it can be based upon the grate of the producer, 1 square foot being allowed in the main for 8 square feet of grate area. Smaller mains are often used, but are not advantageous, and larger mains are desirable.

Valve Troubles. — The reversing valve is the weak point in most furnaces, as the valve losses are a great deal higher than usually considered, often running as high as 10 to 20 per cent of the total fuel consumption. A great many attempts have been made, with more or less success, to design valves which will prevent or at least reduce the losses by leakage and during reversal. Water-seal valves are tight as long as the seal holds, but as the depth of the seal is limited, any excess in gas pressure or in the intensity of the draft will break the seal and a great deal of gas will be lost before the pressure drops sufficiently to permit the the seal to reestablish itself. In large sizes these valves are so difficult to handle that mechanical power with its added complications and opportunities for trouble is required to throw the valve.

All of the valves in common use burn out rapidly. This is particularly the case with the ordinary Siemens or butterfly valve. In water-seal valves the hoods warp badly, often to such an extent that they do not seat properly. Brick lined hoods have been tried to avoid this trouble and are but partially successful, as additional weight makes the valve harder to throw and adds considerably to the expense of upkeep.

Mushroom valves, both plain and water cooled, are used, but plain mushroom valves burn out rapidly, the stems often

giving out first and causing a very nasty fishing job to get the red-hot valve disk out of the flue so that a new valve can be put in. Water-cooled valves are more durable, but they crack if the water is cut off, and cause trouble. In winter it is almost impossible to prevent the water pipes around an open-hearth plant from freezing, particularly during the Sunday shutdowns, etc., when it will not be discovered for some time. There is more danger from this when sudden cold snaps occur unexpectedly and, while the damage to the valve may not amount to much, sufficient cold air may be drawn into the furnace to cause considerable damage to the brickwork, this being particularly the case with water-seal valves. In using mushroom valves for reversing, a large amount of brickwork and excavating is necessary, four valves being required for the gas and four for the air. They must be so arranged that the valves to the stack flue close before the supply valves open, and while it is comparatively simple to secure this result, more or less rigging is required, depending upon the relative locations of the valves. The seats for mushroom valves should be beveled sharply enough to prevent any small obstructions lodging on the seat which would prevent it from closing tightly.

Producer Grate Area. — In regard to the producer grate area required, the gasifying capacity of the producers must be sufficient to supply the maximum demand, and there must be some reserve to permit of cleaning, etc. The following table gives the gasifying capacity of some of the leading makes of producers, and while with expert gasmakers and good coal it is possible to get these results, the output under usual working conditions runs from 20 to 40 per cent less, a part of this deficit being due to the coal and the balance to the labor employed.

Producer	Grate Area Square Foot	Pounds per Hour	Pounds per Square Foot of Grate per Hour
Duff, 12-foot	63	1,400	22.3
Duff, 10-foot	49	1,120	23.0
Swindel, 12-foot	..	1,500	...
Talbot, 10-foot	46	750	16.3
Forter, 10-foot	50	750	15.0
Morgan, 10-foot	78	...	*7.5 to 11.0
	49	625	†12.7
	..	800	‡16.3

*Test at Illinois Steel Company.

†Usual conditions.   ‡Forced.

The last three results were actual operating conditions in mill practice and are probably as good as will be obtained in such cases. The first five items give the gasifying capacity named by the makers, and it is probable that these figures could be exceeded by operating the producers to the best advantage, but such conditions are rarely obtained in practice.

A rule of thumb is " 3.5 square feet of producer grate per ton of furnace capacity." The following table gives the ratio of grate surface used in furnaces of varying capacity:

Furnace	Producer	Producer Grate Area Square Feet Total	Per Ton
10-ton Rechitza	Siemens	28.4	2.84
15-ton Wellman-Seaver	2 Talbot, 10-foot	92.0	6.15
20-ton Alliance, Ohio		100.0	5.00
35-ton Pittsburg		...	4.80
40-ton Grand Crossing	3 Morgan, 10-foot	234.0	5.85
50-ton Ill. Steel Co.	4 Morgan, 10-foot	312.0	6.24
50-ton Lukens	4 Talbot, 10-foot	184.0	3.68
50-ton Ohio	4 Duff	252.0	5.04

Flue Areas. — Following is a table of air and gas valves and stack dimensions:

Furnace	Valves Air	Gas	Stack Diam. Ft.	In.	Height Ft.
15-ton	27-in. Butterfly	24-in. Butterfly	4		90
20-ton Alliance, Ohio	27-in. Forter	27-in. Forter			100
25-ton Wellman-Seaver	36-in. Forter	32-in. Forter	5		125
35-ton Illinois Steel Co.	33-in. Mushroom	33-in. Mushroom			...
35-ton Bridgeport, Conn.	33-in. Forter	30-in. Forter	4	8	114
40-ton Homestead			5		140
50-ton Duquesne			5	6	150
50-ton Illinois Steel Co.			6		160
50-ton Wellman-Seaver	48-in. Butterfly	42-in. Mushroom	6		150

The area of the flue leading from the reversing valves to the stack should be about 25 per cent greater than the area of the stack, but no flue should be so small that a man cannot get through it. In the above it will be noted that the area of the gas valve is about 80 per cent of that of the air valve, and the combined area of the air and gas valves is from 60 to 70 per cent of the stack area.

Following is a table of air and gas port areas:

Furnace	Air Port Square Feet	Gas Port Square Feet
50-ton Laughlin....................	18.4	6.85
50-ton Unknown....................	14.5	8.10
40-ton Homestead....................	14.25	8.0
50-ton Homestead....................	18.0	8.0
50-ton Duquesne....................	18.0	10.5
20-ton Alliance, Ohio....................	12.5	2.81

In the Alliance furnace there are three air uptakes having
a total area of 4.23 square feet, and two gas uptakes having a
total area of 2.81 square feet. In this and the first two of the
above furnaces the air port is very nearly the width of the hearth,
and about 125 feet in height. In the 50-ton Homestead and
Duquesne furnaces the uptakes are of the same area as given for
the ports, — that is, in these furnaces there is practically only
one port into which the air and gas uptakes debouch. These
furnaces are fired with natural gas, but are so designed that they
can be altered to use producer gas.

Arrangements of Ports. — The ports of an open-hearth
furnace should be so arranged that the gas is spread out over
the width of the hearth beneath the air, and the gas and air
should be brought together just before they enter the heating
chamber. As most furnaces are arranged there is a dead place
at the end of the hearth at which the gas and air are entering
the heating chamber, and the hottest part of the flame is close
to the exit ports, extending down into the checkers in many
cases, where combustion is undesirable.

In modern furnaces the air and gas leave the regenerators
by an opening in the end wall of the regenerator chamber, pass-
ing into the cinder pockets, from which the uptakes lead to the
ports. False arches are so arranged that the cinder pockets
can be cleaned with a minimum amount of trouble. In many
cases false arches are placed in the back of or to the sides of
the uptakes, and in some cases in the walls surrounding the
regenerator chambers.

Casting Methods. — The most common arrangement of
an open-hearth plant places the furnaces in a single line, having
on one side the charging floor, covering the regenerators, and in
some cases the reversing valves, then the stock yard and the
producer house; on the opposite side of the furnaces are the
casting house and mold yard. In small plants and where bottom

cast ingots are turned out casting pits are employed, and this method is also used where large ingots of special sizes must be made, as for armor plate and large forgings. Plants having a large output generally make top cast ingots, casting on cars, this method being more rapid than casting in a pit. A few open-hearth plants, notably the Homestead No. 3, are arranged with a double line of furnaces, with the casting house between them. This arrangement has serious disadvantages, and it is not likely that the arrangement will be copied.

In a few plants one of the furnaces has been arranged with a removable roof so that salamanders too large to be charged in the usual manner can be charged in the furnace and melted up. An arrangement of this kind is convenient, as it enables the plant to dispose of accidental run outs and other scrap of this character in such a manner that they are not a total loss.

OPEN-HEARTH CASTINGS *

By W. M. CARR

IN view of the growing interest in the production of steel castings and their increasing utility, it is proposed to pu⁺ before the readers of " The Foundry " a series of articles treating of the salient points of their manufacture by the acid and by the basic open-hearth processes. The articles will cover, (1) the selection and representative compositions of melting stocks, alloys, refractories, fuels, molding sands; (2) furnace construction, melting, manipulation of heats; (3) conditions of molding as affecting physical properties of products; (4) analysis and physical tests of different grades of product; (5) effect of constituent metals and metalloids usually present in open-hearth steel castings; (6) heat treatment or annealing, with notes on the microscopic examinations in connection therewith; (7) blow-holes, shrinkage-cracks, etc., with a discussion of their causes; (8) repairing of certain defects by thermit welding; (9) special or alloy steel castings.

MATERIALS FOR ACID PRACTICE

Melting Stock. — The composition of materials for acid castings comes within well-defined limits, for the main reason

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* " The Foundry," December, 1905.

that the process is nearer a melting, rather than a refining one, owing to the fact that the metalloids, sulphur and phosphorus are not removed during the conversion of the charge. As their presence in the finished product must be subject to specification, it follows that the melting stock must be bought with a limit to the contents of the elements named. Only in regard to quantities of sulphur and phosphorus exists the distinction between acid and basic melting stock. Pig iron for ordinary practice analyzes as follows:

Total carbon	2–3.5 per cent
Silicon	.50–1.5 ,,
Sulphur	.04 or less
Phosphorus	.04 ,,
Manganese	.50–.75

In addition to pig iron, steel scrap known as " basic scrap " is also bought on analysis or chemical specifications. Being the product of rolling mills, etc., following basic practice, the contents of sulphur and phosphorus are usually low, and they are the only elements of composition taken into account. A representative analysis of steel scrap for acid practice is as follows:

Sulphur	.015–.03 per cent
Phosphorus	.010–.03 ,,

Since the physical character is usually represented by billets, crop ends, blooms, plate-shearings, defective castings and waste metal from steel foundries, the nature of them necessarily predetermines the composition in regard to the presence of carbon, silicon and manganese. With a charge of pig iron and steel scrap it is comparatively easy to keep the composition of finished product within acid specifications.

REFRACTORIES

Silica sand forming the hearth of the furnace, known chemically as an acid, lends its classification to distinguish between the two processes. It does not present a condition wherein certain elements are removed during melting of stock, namely, sulphur and phosphorus. The amounts of those elements charged will be found in the finished product. The func-

tion of silica sand is mainly a refractory one. That is, it must have heat-resisting qualities, but not to the extent that it will not set or sinter slightly to satisfactorily preserve the contour of the shallow dish-like formation of the hearth. It must not be too fusible, otherwise there would be excessive scorification or cutting of the hearth. It must set or sinter sufficiently to resist abrasion due to the charging of stock. It is difficult to lay down strict chemical specifications for silica sand. There are certain conditions of composition not expressed by an analysis of the total constituents. The combinations of them with their neighbors cannot be ascertained. However, a silica sand of the following analysis gave excellent results in practice:

Water	.24	per cent
Silica	97.25	,,
Alumina and iron oxide	1.52	,,
Lime	.16	,,
Magnesia	.08	,,
Alkalies	.39	,,
Loss on ignition	.36	,,

There are several deposits of silica sand in the West and middle West that are supplied to steel foundries, and no difficulty will be found in getting the best quality for the purpose. As a general rule a silica sand for hearth lining must be low in lime, magnesia and the alkalies (potash and soda); an excess of any tends to lower the fusion point of the sand, destroying its required sintering or refractoriness. Usually a silica sand with less than 95 per cent silica will not answer for a refractory.

FUEL

It is a question of local conditions as to whether the fuel may be natural gas, oil, tar or producer gas. Natural gas is by far the most satisfactory, owing to its high calorific value and its non-contamination of the bath or molten charge. It is fed directly into the working body of the furnace without any preheating or a passing through the regenerator chambers. Oil, next in efficiency, may be crude petroleum or a grade known as residuum, a by-product of petroleum distillation. The heating values are high, and in certain grades the composition will answer for acid work. Some grades are rather high in sulphur, which is absorbed by the stock in melting.

Tar has been satisfactorily used when available as a by-product in the manufacture of coke by Otto-Hoffman retort ovens. The construction of burners permitted a simultaneous burning of the gas resulting from the coke retorts.

Producer gas is used extensively and, when near a reliable supply of coal, considered cheaper than the aforementioned fuels. A description of gas producers and liquid fuel burners will be given in subseqent chapters. Gas distilled in a producer does not have as high a heating value as liquid fuels, nor is the efficiency so great, because much of the total heat units are lost in the process of distillation of the coal (soft or anthracite). With liquid fuels or natural gas the total thermal efficiency is available within the working body of the furnace, there being no intermediate losses before delivery at the point of combustion. Natural gas or liquid fuels are easy of control in flame regulation; furnace construction and repairs are simplified and lessened; regularity of product and longer campaigns are assured. Producer gas is irregular, and owing to heavy deposits of tarry and sooty matter, regular weekly stoppages must be made to clean out mains and flues. Liquid fuels or natural gas eliminate such losses of working time.

HEATING VALUE OF FUELS
B. T. U.

Natural gas	300–600	per cubic foot
Oil	14,000–17,000	per pound
Tar	15,000	,,
Producer gas	100–150	per cubic foot
Bituminous coal	10,000–12,500	per pound

One ton of bituminous coal yields in a moderate producer, 160,000 cubic feet of gas with 65 per cent efficiency in heating value of the coal.

ALLOYS

Ferro-Manganese. — The standard quality contains 80 per cent manganese. A representative analysis will be as follows:

Iron	12–14	per cent
Manganese	80.00	,,
Carbon	5–6	,,
Silicon	.5 –1.00	,,
Sulphur	.010– .03	,,
Phosphorus	.100– .75	,,

Ferro-Silicon. — The standard grade carries 13 per cent silicon and is usually sold on a guarantee of 11 per cent of that element. The following is a usual analysis:

Silicon...................................... 9– 13 per cent
Carbon...................................... 1– 2 ,,
Sulphur..................................... .04–.08 ,,
Phosphorus................................. .10–.50 ,,

In recent years there have been put on the market several grades of electrolytic silicons that are very satisfactory. The most economical grade is the one carrying 50 per cent silicon, and considered on the basis of the unit cost of silicon, is cheaper than the commoner alloy. The following is a typical composition of an electric furnace ferro-silicon:

Silicon..................................... 50–52 per cent
Iron....................................... 44–46 ,,
Carbon..................................... .15 –.25 ,,
Sulphur.................................... .003–.010 ,,
Phosphorus................................. .04 –.06 ,,

The purposes of the aforementioned alloys will be considered farther on.

Iron Ore. — The purpose of iron ore is twofold. One is to increase the fluidity of plastic slags, the other as a carrier of oxygen to assist in the removal of the carbon from the bath of molten metal. The total iron liberated in the interchange between its oxygen and the carbon of the bath adds to the yield of metal. The most satisfactory ores for open-hearth practice are the magnetites or hard hematites. The soft ores are apt to dissipate their combined usefulness in the slag instead of oxidizing carbon. No particular limits are placed on their compositions, excepting that they be high in iron and moderately low in phosphorus. A fair analysis is as follows:

Iron....................................... 60–68 per cent
Silica..................................... 1–5 ,,
Sulphur.................................... .05–.100 ,,
Phosphorus................................. .03–.500 ,,

Molding Materials. — Since all steel castings are poured at higher ranges of temperature than gray iron or malleable castings, it is essential that the sands and clays (binders) be as refractory as possible. Pure silica is the most desirable — the

purer the better. The following is an analysis of a typical steel molding sand:

Silica	98.5	per cent
Alumina	1.40	,,
Iron oxide	.06	,,
Lime	.20	,,
Magnesia	.16	,,
Combined water	.14	,,
Alkalies	.25	,,

It must be of such a nature or structure physically that the heated gases in the mold when displaced by liquid steel will have a free passage outwardly. It is preferable that the grains be sharp and irregular rather than rounded, as would be the case with sand subjected at some time to the action of water. The color is often white or slightly tinged with yellow. Its color is not necessarily a guide to its qualities, but it is often an indication.

Fire Clay. — Pure silica sand having no binding properties, varying amounts of clay are mixed with it to give the sand a needed bond and substantiality to the mold prepared for the reception of the hot steel. The clay must also be refractory and possess a maximum degree of plasticity. Low-grade sands and clays would fuse at the temperature of liquid steel, and cause the castings to be of an irregular, rough surface. An attempt to economize in the sand pile is apt to spoil one's reputation for clean looking castings.

It is not always reliable to have recourse to chemical tests on refractories or molding materials, since actual practice will affirm the desirable qualities in them. The following is a typical composition of fire clay:

Silica	60 –66	per cent
Alumina	25 –20	,,
Iron oxide	nil–2.00	,,
Lime	nil–1.00	,,
Magnesia	nil–1.00	,,
Alkalies	nil–2.00	,,
Combined water	7.50–10.50	,,

The value of a fire clay depends largely upon a low content of alkalies and a freedom from carbonates of lime. Oxide of iron has a strong fluxing effect, but its presence below 3 per cent is harmless.

Core Compounds. — Any reliable proprietary article will answer, and the list will include molasses water, rosin, flour, linseed oil, etc., all of which are too well known to need any description.

MATERIALS FOR BASIC PRACTICE

Melting Stock. — In this particular, basic melting possesses a marked flexibility in selection of stock over acid melting. It is by some considered a sort of metallurgical scavenger. While it is true that there are greater latitudes in quality of pig iron and scrap, yet it must not be overlooked that the promiscuous dumping of any kind of stock into a basic furnace cannot yield a reliable product. If good castings are the object sought, discretion must be observed in the selection of materials entering into their manufacture. In regard to quantity, basic pig iron greatly exceeds acid pig so far as availability is concerned. The ores of the southern and southwestern states are plentifully endowed by nature for the yield of unlimited supplies of basic pig. As to scrap, the situation is somewhat of an uncertainty, owing to the inroads made by the larger interests engaged in the production of ingots in basic bottoms; in consequence, prices for scrap have a tendency to gradually rise. The factors controlling the choice between basic and acid practice for castings are ones of location and contiguity to the sources of supply of raw materials. So far as the relative value of the product of either process is concerned, it is true that basic castings are fully as satisfactory, from the viewpoint of quality, as those made by the acid process. It must be remembered, one is a melting method and the other a refining one. The basic process to get good results needs intelligent handling and a higher development of melting skill. The pig iron necessary is known as " standard basic," and the following analysis represents the ulterior limits in composition.

Silicon	1.00	per cent
Sulphur	.05	,,
Phosphorus	1.00	,,

" Off-basic " can carry as high as 1.50 silicon and again as high as .07 sulphur. Shipments of these grades on standard contracts can be accepted at a concession in price and it is permissible to use a moderate amount of " off-basic " in charges with no harm to follow. As was mentioned under " Acid Melt-

ing Stock " the sulphur and phosphorus charged in that process would equal that of the finished product. In basic melting it is possible to eliminate 50 to 75 per cent of the sulphur and 95 per cent of the phosphorus, thanks to the character of the lining of the furnace and slags formed by the liberal additions of limestone with the charge. For castings it is desirable to have on hand several brands of basic pig, some with low phosphorus and some with high manganese. Certain brands can be obtained with phosphorus as low as 200, while standard in other particulars, and at ruling prices. Brands with high manganese ranging from 1.5 to 3.00 per cent command a higher price. It is not good practice to make the entire pig-iron charge high phosphorus stock. The reasons for mixing brands in regard to phosphorus and manganese will be considered under furnace manipulation.

Steel Scrap. — The character of this material is not considered chemically, because the physical nature of it brings it well within working limits as to composition. It is usually designated " heavy railroad melting scrap," but liberties are sometimes taken, and unless the consumer exercises circumspection, almost everything may be found in it, from shop sweepings to tomato cans. *Heavy* scrap is the desideratum, and may consist of, as an illustration, steel rails, knuckles, draw bars, wheel centers, car-springs, fish-plates, defective castings (steel), ingots, etc. Gray iron castings should be religiously excluded when sold as steel scrap. It is allowable to use limited quantities of defective malleable castings, although draw bars of such materials are sold as steel. Five per cent of the scrap charge in malleable scrap will not upset the melter's calculations. The scrap charge will be augmented by daily waste from the foundry.

REFRACTORIES

The hearth of basic furnaces in American practice is made with magnesite, a substance classified chemically as a base and possessing the quality, in addition to resisting high temperatures, of being but slightly affected by a slag highly charged with lime, which would be fatal to a hearth lined with silica sand. To lengthen the life and efficiency of a basic hearth the first consideration is to keep out of the charge as much siliceous matter as possible. Magnesite, the carbonate of magnesia, is an importation from Austria, where it is calcined, converting it into mag-

nesia, the oxide of the metal magnesium, by the removal of the major portion of carbon dioxide. It is still considered commercially as a magnesite. Its composition ranges as follows:

Raw

Magnesium carbonate......................	93.19 per cent
Calcium carbonate.........................	1.43 ,,
Iron carbonate............................	2.61 ,,
Silica....................................	2.75 ,,

Calcined

Magnesia.................................	90–95 per cent
Lime.....................................	1–2 ,,
Iron oxide...............................	.5–3.50 ,,
Silica...................................	.5–2.75 ,,
Volatile matter..........................	.5–1.00 ,,

Dolomite. — This material is extensively deposited in the United States. It is a double carbonate of lime and magnesia. It is used either calcined or raw. Principally it is used for patching slag lines, where scorification of the hearth is the heaviest. It is not recommended for points below the slag line. A typical analysis is as follows:

Raw

Silica....................................	.5–2.00 per cent
Iron oxide ⎱	.5–2.00 ,,
Alumina ⎰	
Calcium carbonate........................	50–55 ,,
Magnesium................................	40–44 ,,

Calcined

Silica....................................	.5–2.00 per cent
Iron oxide ⎱	.5–2.00 ,,
Alumina ⎰	
Lime.....................................	50–55 ,,
Magnesia.................................	37–45 ,,

Chrome Ore. — A substance highly refractory to heat and neutral to the action of acid and basic slags. Unfortunately, it has no bond, and for that reason its uses are somewhat limited. It is used for patching parts of the hearth where cutting above the slag line is severe upon the brickwork, usually in gas ports

and door jambs. (In European practice it is stated that entire hearths are lined with lump chrome ore.) Aside from patching, it is used as a neutral lining between magnesite and silica bricks. Its composition is as follows:

Chromic oxide . . . . 40–60 per cent
Iron . . . . 15–18 ,,
Aluminia . . . . 5–30 ,,
Silica . . . . 1–5 ,,

FLUXES

The most efficient in basic melting is ordinary limestone. Its function is to form a slag that will readily absorb the sulphur and phosphorus of the charge and act as a vehicle for the oxidizable silicon, iron and manganese. The purer the grade the better, that is, a richness in carbonate of lime and a freedom from silica.

A fair analysis is as follows:

Silica . . . . .25–1.00 per cent
Oxide of iron and alumina . . . . .50–2.00 ,,
Carbonate of lime . . . . 95.–99.00 ,,
Carbonate of magnesia . . . . .5 –1.00 ,,

Fluorspar. — The function of this material is to thin a limy slag when in the judgment of the melter it seems thick or sluggish. A moderate addition of fluorspar will liven it and its action may be likened to certain fluxes used in brazing metals — the property of dissolving at higher temperatures metallic oxides. It is plentifully deposited in the United States. A good grade will analyze as follows:

Calcium fluoride . . . . 90–98 per cent
Oxide of iron and alumina . . . . .5–1.00 ,,
Silica . . . . nil–1.00 ,,

Iron Ore. — See " Acid Melting Materials."
Alloys. — See " Acid Melting Materials."
Fuels. — See " Acid Melting Materials."
Molding Materials. — See " Acid Melting Materials."

As a guide to purchasing stock the following tabulations will be of assistance in furnishing approximate amounts for regular consumption. The figures are based on the different kinds of stock necessary to produce 1 net ton of castings:

	Acid Practice	Basic Practice
Pig iron.......................	620 pounds	1,227 pounds
Steel scrap	1,880 ,,	1,227 ,,
Ferro-silicon	54 ,,	57 ,,
Ferro-manganese...............	28 ,,	35 ,,
Iron ore	26 ,,	30 ,,
Chrome ore	.....	5 ,,
Aluminum.....................	3–10 pounds	3–10 ,,
Limestone.....................	.....	300 ,,
Dolomite......................	.....	85 ,,
Fluorspar......................	.....	13 ,,
Magnesite.....................	.....	34 ,,
Silica sand	1,800 pounds	1,600 ,,
Fire clay	300 ,,	350 ,,
Gas coal	950 ,,	1,250 ,,
Fuel oil	55 gallons	80 gallons
Boiler coal (power)	900 pounds	900 pounds

NICKEL STEEL *

THE excellent report of the Alloys Research Committee which was read at the meeting of the Institution of Mechanical Engineers on Friday evening presents many points of considerable practical value to the engineer. One pronounced fact is the extraordinary influence of quite small changes in the composition of alloys of the kind tested. A glance at the diagrams shows that the addition of .7 per cent of nickel suddenly converts the steel from one having fair tensile strength and ductility into an exceedingly hard and strong metal with only 2 per cent elongation, a metal which breaks almost suddenly like a chisel, a defect which does not disappear by further additions of nickel till over 16 per cent enters into the composition. The significance of the fact will not be missed. It must be borne in mind that the amount of metal used in these experiments was very small, and, no doubt, each ingot was homogeneous; but would it be possible, as Captain Sankey asked, to forge a shaft, for example, with a full certainty that the nickel content was either below 4.25 or so far exceeded it that the brittle zone was safely avoided and the qualities of the remarkable alloy K approached? If not, we might obviously have a forging of

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* "The Engineer," November 24, 1905.

which the greater part was all that could be desired, whilst locally it might be as brittle as glass. Needless to say, such a material would be nearly valueless, and one of the problems that the makers of this class of alloy for industrial purposes will have to solve will be the means of insuring absolute homogeneity in metals that come anywhere near what we may describe as the danger zone.

A curious fact about the alloy K is emphasized by italics in the report. It is that the metal " is by no means easy to machine *except at the very beginning.*" The vibration caused by machining sets up in it a change of structure, and from a comparatively soft metal it becomes hard. An explanation is given of the fact, but we must not allow ourselves, as occasionally happens, to be blinded by it to the extraordinary phenomenon which is here presented. The fact has been recognized for many years and enforced by a hundred accidents that steel undergoes a pronounced advance towards brittleness by prolonged agitation, but we are unable to recall any previous instances of a metal changing its nature in the short time that is required to machine its surface. We are not prepared to say that such instances do not occur, and now that a reason for their occurrence has been adduced — the change from polyhedral to martensitic structure due to mechanical work — it may well be that we shall hear more of the appearance of unexpected hardness or hard spots in steels during machining. It is to be hoped that one or other of the authors of the paper may be able to pursue the inquiry further, and to tell us what are the conditions under which such a curious circumstance may arise. For example, what is the lowest percentage of nickel, if, as appears, it is the nickel that is responsible, that is essential to such unstability of nature? We are told that the alloys E to J are hard to machine on account of their martensitic structure. Alloy K, which differs mainly from F in having a great deal more nickel in its composition, has a polyhedral structure at first, which rapidly changes to martensitic when it is machined. J also differs but little from K, save in nickel, of which it contains 4 per cent more, but J is hard from the first. In this narrow range, then, of 4 per cent, the nature of the metal must change. It would, we venture to think, be not only interesting, but valuable, to pursue the inquiry into this particular problem further. K is an alloy with extraor-

dinary properties; it is at present not likely to be used in the arts, but if ever it should be, the phenomenon to which the reporters have called attention, all too briefly, would demand earnest attention.

There is one other section of the report of great industrial importance. It refers to the corrosion of nickel steel. We are disposed to think that the reporters have not sufficiently considered the importance of this part of the inquiry which, considering the bearing it has upon the practical use of nickel alloys, is of greater moment than the micrographical investigation into which they go with great thoroughness. Leaving out the sulphuric acid test, which is of little consequence, the resistance to corrosion in sea or fresh water, under the conditions of test, is practically constant for all the alloys — that is to say, that corrosion does not decrease as nickel augments, or, at any rate, to a negligible extent. Unfortunately, it does not seem to have occurred 'to the experimenters that a few samples of ordinary mild steel should have been treated in precisely the same way and used as a basis of comparison. We do not hesitate to say that not one engineer in ten thousand could say what is the percentage loss of weight by corrosion of steel in sea water, and hence, save for comparison among themselves, the results given in the paper are of little value. We might go further and say that tests of the kind could never be of much industrial value — a point which was brought out by Mr. West when he referred to the fact that the rate of corrosion varied inversely as the thickness of the plate, and by Sir William White when he asked for the surface loss in place of weight loss. We may refer also to a paper by MM. Frémont and Osmond, dealing with the corrosion of boiler plate, which appears in the current issue of " La Revue de Métallurgie," and which also bears out the same point — that the rate of corrosion depends upon the conditions as well as the nature of the material. We mention this, as it is possible that a steel which would resist corrosion in a tranquil state might be more readily a victim to it in actual practice than one that appears less good under test. Why should not an elaborate test of corrodibility — a very important matter from the constructional engineer's point of view — form part of such inquiries as this?

ABSTRACTS *

TENDENCIES in the Foundry Industry. Richard Moldenke. Paper read before the New England Foundrymen's Association, Boston, Mass., December 13, 1905. — The author describes the tendency towards multiple operations in the American foundry, where not infrequently thousands of pieces of a kind are cast and finished for stock, the latter being replenished when it falls below a certain minimum. This method results in producing work at the cheapest rate. It also implies the extensive use of molding machines. The author believes that the treatment of the sand does not receive in American foundries the attention which it deserves. The growing demand for foundry standards is next dealt with in the paper, the author's remarks being in part as follows: "There is a growing demand for foundry standards. Thus, flasks, pattern work and the mold-

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ing methods depending upon the close coöperation of the
pattern shop with the molding floor are coming in for consider-
able attention. The makers of molding machines will be greatly
benefited by this desired standardization of flasks, for the time
has now gone by when a manufacturer would go out of his way
to get the most impossible screw thread in order that the repairs
subsequently necessary would have to come to him. We shall
undoubtedly see the day when all the designs of the drafting
office of an industrial establishment will go for revision to its
foundry superintendent in order to standardize the non-essential
elements therein and create less labor in producing the castings."

On the subject of the use of steel scrap in the cupola and of
the advantages of the " air furnace " the author writes:

" Turning now to the melting and the closely allied labo-
ratory, we see that the most strongly marked feature is the pro-
duction of higher grade castings by the addition of steel scrap;
or, in other words, the reduction of the total carbon in cast iron,
making the crystalline structure more closely adherent and
hence the whole casting stronger. Here the skill of the melter
is joined with that of the chemist, so that value is received from
the higher priced stock charged into the cupola. The cupola
process is being studied more carefully, and experts in that line
can produce results close to those of the air furnace or open
hearth. Considering that this is accomplished with fuel and
metal in contact and by a notoriously unsatisfactory melting
method, which the cupola process undoubtedly is from the stand-
point of the treatment the metal gets in it, the foundry industry
is to be congratulated upon its ability to retain a strong hold
on the making of castings in the face of the hard knocks it is
getting from the steel casting establishments. This movement
toward better grades of metal is but in its infancy. The cupola,
which is a cheap melter, will undoubtedly be improved with the
view of getting better results from the steel scrap additions.
The metal will be safeguarded more from burning and the addi-
tions of the scrap will be systematized more, so that a given
quantity will produce given results more regularly than is now
the case.

" The tendency above-mentioned has somewhat retarded
the introduction of air furnaces in general foundry practice.
However, taking into consideration the demand for better irons,

better coke, better melting methods, the specialist founder will soon tire of buying high-class material and spoiling it or taking big chances in that direction. He will naturally revert to the air furnace as better able to give high-class results from high-class material, and the consumer will be glad to pay the difference."

The latter part of the author's paper is of a suggestive and prophetic character and is reproduced in full below.

" Those who have taken the trouble to follow the silver and copper market will have noted that the high levels reached are not due to spasmodic fluctuation made by financial manipulation, but are the result of a real ability on the part of the civilized world to absorb these metals. We have the same thing in the iron market. The swing of the pendulum from the 22,000,-000-ton mark will soon carry the consumption of the metal far into the thirty or forty millions, and unless the country can produce this quantity steadily the price is bound to rise sharply. To-day we find few men in our line of work who are out for abnormally high prices for their product. We all wish for nothing better than a fair profit on base purchase prices which are fair to the furnace and coke dealers as well as to us. Hence, the output of our establishments will be kept as much as possible within conservative price limits and the quantity will be made to increase gradually. It may be said, however, that the resources of the country will not be able to respond quite as fast as the demands the rapidly increasing population is making upon them, and hence we will never see the days of 1894 prices again, for which let us be thankful. All this means that with better prices, even if pig iron and coke hold well up, a more liberal tendency in the way of investment is bound to manifest itself, and everybody will be the gainer.

" Whereas once the melting point of the various cast irons formed the one absorbing topic for articles and discussion, at present it is the elimination of sulphur in the cupola. This is a good sign, and even if one man finds that he cannot get the results of the other, and therefore we are at present quite at sea regarding a desirable method, yet it shows a tendency, and a good one.

" With more light on this question it is but a step to work on others, and finally we may get down to a closer study of the

burning effects manifested in cupola and air-furnace practice, which I hold are the most important by far of all the phenomena of the foundry melting processes, granted that the chemical composition is otherwise correct.

" This leads us to the use of the ferro alloys in the foundry to correct the evils we know and others we have a vague apprehension of. To-day the use of ferro-manganese and of aluminum is quite extended and is really a help in many instances. With the poor pig iron, and especially the very poor coke, the smaller founder is forced to put up with, the use of either of the above-mentioned correctives is to be recommended. Unfortunately ferro-manganese is hardly powerful enough to do much good in the foundry unless the mixture has a goodly proportion of steel in it. When this is the case it means a higher melting point, and, with higher temperatures than ordinary cast iron is apt to be poured at, much of the oxidation is removed and we avoid the pin holes and other weakening and unsightly effects which seem to be somewhat the rule at the present day. The real foundry alloy, however, is still to be discovered and made commercially, and its day cannot come too soon.

" I look forward to great improvements in the making of producer gas. We hear of mysterious developments across the water, by which a more powerful heating agent is secured. How far the reports are true we cannot say, but that work is being done in that direction is certain. It may mean a cheaper and more powerful fuel gas, and if so it has a good place in the modern foundry, for whoever has worked with gas instead of coal will stick to the former until the price soars out of sight. Whether we are to have the open-hearth furnace in the big foundries or the making of electricity with the gas engine in the smaller foundries for use in melting time, will determine; but it is well to keep this development before us and to profit thereby.

" This brings us to the consideration of another matter. The Canadian government is doing much to foster the development of electric smelting. The makers of the latest types of electric furnaces are constantly getting better efficiencies. Now with a cheap gas in a gas engine and for the making of very small castings in small quantity there is no reason why the small steel and bronze foundries should not melt their stock in the electric furnace. The higher price of the work sold will prob-

ably stand this. This matter will bear watching. I have recently noticed the suggestion of Dr. Waldo, of New York, for the making of Bessemer steel rings or suitably shaped small ingots, these to be of the composition of the steel casting. Now by charging these small ingots into the electric furnace one obtains a fluid steel of the proper composition to cast. I would suggest as an improvement that the ingots be preheated up to the highest point possible without injury to the metal — say, just as the ingots for rails or structural steel are treated. This would leave for the more expensive electric current only the finishing heat necessary to melt and superheat to the point right for pouring.

" The considerations presented above will show our foundrymen that we are by no means through with the improvement of our processes, and were it possible to enlist an active encouragement on the part of the industry, many of these very direct problems could be attacked and possibly solved.

" Finally, we come to the general problems of the foundry, in which there are also marked signs of a change. This will probably affect only the very large industries for the present and next generation, but what may come after is hard to say. Foremost stands the rapidly increasing use of direct metal. This is more marked across the water, but is bound to come here also. The big segments for the tunnel shields and linings should never have been made of remelted metal. However, this does not mean that it was advisable from the first to jump into a new method for such vast contracts. Here again we strike the importance of the use of steel scrap in gray iron castings in order to reduce the total carbon. I would not advocate the use of direct metal just as it is, but to have the stream of metal from the blast furnace go into large heated mixers, which means greater — in fact, more easily attained — uniformity than is ever possible with the cupola. Now into this mixer there should be charged successively quantities of steel scrap which has been heated up almost to melting. This accomplishes a twofold purpose. First, it gives a reduction of total carbon without lowering the temperature of the metal in the mixer too seriously to be corrected at once by the heating method used, as well as the comparatively large quantity of metal that should be in the mixer all the time. Now, the first

result is the making of a high-grade cast iron. This iron should be good enough for all the purposes the process could be used for, such as the making of pipe, tunnel segments, ingot molds, etc.

" The second effect of the addition of the preheated steel scrap is that the problem of kish is done away with. This is the bugbear of the direct metal foundry, and in fact has retarded the introduction of direct metal for important work so much that at one time it was thought out of the question to think of ever going back to this ancient way of making castings.

" What, then, will be the result of this tendency? It means that blast furnaces will be located wherever the raw materials not only are favorable, but where there is a good shipping point for pipe, possibly car wheels and not impossibly malleable castings for car work. The furnace proposition will then become one of allied industries to give an outlet for the pig iron made which will fit these uses, and all the pig iron not of composition to go into the various mixers will be put upon the market.

" While this seems visionary, it is nevertheless a fact that one very large combination is about to break ground for just such an establishment, and we may hear from direct metal pipe very soon. With our American enterprise one hesitates to say just where these changes in method of production as well as administration will end, and it is even within the range of possibilities to find stoves made at a blast furnace once the molding machine has conquered the field that is before it in that line.

" It remains for the men at the very top of our great industrial establishments to solve the fine points in producing enormous quantities of high-grade castings and to make them cheaply. These men are to be found in our foundrymen's associations, in our great engineering societies and wherever the active individuals of our industry get together to discuss questions of practice. I venture to say that without our progressive institutions of this kind the entire foundry industry would be what it still is in some of our large cities, where the pig-iron salesman makes the mixture and the ignorance of the customer makes the price."
No. 444. A.

The Preparation of Molds for Steel Castings. Arthur Simonson. Paper read before the Philadelphia Foundrymen Association. 2,800 w. — The author first remarks that it would be impossible

to give any fast rules by which to prepare satisfactory molds for steel castings because of the many varying factors and conditions which must be taken into consideration, to say nothing of the personal equation. Rules which might work properly in one plant might be found unsatisfactory elsewhere where the conditions are different. It is only possible to generalize on the subject. The first requisite is a " good molder," which does not mean a man with muscle only, but with brain as well. The second requisite is a refractory material capable of standing the high temperature of the steel (about 3 000° F. in most cases). This material is essentially silica, and the difficulty, where it arises, is to obtain it sufficiently pure, the chief impurities being lime and magnesia. In America, however, very pure sand (containing as much as 98 per cent SiO_2) is readily obtained. The quality of the sand for molding purposes depends upon its proximate rather than upon its ultimate analysis. The sand should be plastic, and this plasticity is imparted through the presence of a small amount of clayey matter or alumina.

In one sand the percentage of alumina may be high, but it may be combined with the silica and the sand will not be plastic. In another sand a less proportion of alumina in the free state will make the sand adhesive and consequently fit for molding. It is better to start with a pure quartz sand and then give to it sufficient body for different purposes by adding varying proportions of a pure clay of known analysis. Analysis of three samples of quartz sand obtained from different parts of the United States are as follows:

	One Per Cent	Two Per Cent	Three Per Cent
Silica	96.60	98.61	97.61
Alumina, iron	2.57	0.77	1.41
Lime	0.41	0.25	0.39
Magnesia	0.40	Trace	Trace

A suitable clay of very fine quality analyses as follows:

	Per Cent		Per Cent
Silica	71.03	Magnesia	Trace
Alumina, iron	22.51	Water and organic	
Lime	0.35	matter	6.2

Mixing any of the sands and clay mentioned above in proportions to give from 90 to 95 per cent of silica and from 3 to

5 per cent of alumina will give a composition suitable for almost any class of casting. This sand will be much stronger than natural sand as a general rule, and decidedly more uniform.

The inking is generally done in a pan grinder, with heavy chilled iron rollers. Centrifugal mixers are not so successful, for reasons that will be explained later. The sand and clay in requisite proportions being placed in the grinder, they are moistened with molasses water to such a state that, when a quantity is taken in the hand and squeezed, a few grains will stick to the hand. It must not cake on the palm, or it is too wet. Molasses water is used to give greater body to the sand in the green state, and also because it does not evaporate like plain water. The sand is rolled in the grinder for ten to twenty minutes, and if its condition be felt with the hand from time to time it will be noticed that it becomes stronger the longer it is left in. This means that every grain of sand is uniformly coated with clay, and explains why centrifugal mixtures are not so successful. The heavy rollers thoroughly incorporate the clay with the sand, but they should not be so heavy as to crush the grains.

As to the size of the grains, it is wise to use two grades, one quite fine, with rounded grains, and the other much coarser and with more angular grains. The fine part of the sand insures a smooth face, and the coarse part serves to open up the pores and provide a ready means of exit for the gases formed during and after pouring. As regards the strength or toughness of the sand, it should be such that on squeezing some of it in the hand the lumps so formed will retain their shape and sustain a slight pressure between the finger and thumb before collapsing. This is a more delicate way of testing the strength of molding sand mixtures than appears at first sight. The fingers are very sensitive, and sand can be very accurately graded by this means.

Passing to the second point, which concerns the mechanical properties of the mold itself, a mold has to stand an enormous pressure, as all know who have seen clamps burst, and holding-down weights and copes lifted by the rising metal. Not only is there the fluid pressure caused by the weight of steel, and the head due to the height of the ladle, but there is the pressure caused by the expansion of the air and the large amount of gases generated while the mold is being poured. Flasks for steel castings, therefore, need to be heavier and stronger than for

iron castings, and all the accessories, such as clamps, plates, etc., also need to be correspondingly stronger. As for the mold, — that is, the sand part of it, — it must be constructed to stand the strain that is put on it; all projections must be well rodded, the ramming firm and even, and the gates and risers cut in such a manner as to relieve the strain as much as possible. It is wise to run castings from the bottom when feasible.

What happens when the mold is poured full? The steel begins to shrink, and if it is a plain shape, like a sphere or cube, it will shrink away freely from the mold on all sides. But few castings are so simple. They have projections, bosses, ribs, etc., and consequently when they begin to shrink they meet resistance from the mold. At the instant of setting or becoming solid, steel has practically no physical strength; so, if the mold is too rigid, the result will be that the casting will pull apart. We, therefore, need a mold to be very strong at the moment of pouring, and quite collapsible a few minutes after. If the sand is mixed right this will be the case, as a few minutes at such a high temperature will serve to destroy the binder and the sand becomes " rotten " and powdery.

The fact that steel castings are frequently very much warped or. twisted when taken out of the sand shows the resistance that was offered to the free shrinkage of the metal. It is almost impossible to avoid this in some cases, but steps can be taken to reduce it to a minimum. This can be done by ramming cinders, sawdust or shop sand in pockets at the places where the most shrinkage is going to occur. Cracking and warping may be avoided by shaking out the castings while very hot, before the shrinkage has all taken place. This must be done very judiciously, however, or it may result in worse trouble than it was intended to cure.

The smooth face of castings is obtained by coating the molds with a liquid wash consisting of flour silica, a little clay and molasses water. This should produce on the mold when dry a very thin skin, very rigid and with a feel like velvet. It should be possible to rub the powder off to some extent. On this surface the steel will lie quietly without burning in, on account of its specially refractory nature, and it at the same time permits gases to pass freely through it to the more open-grained sand behind.

Referring briefly to the technique of molding, we can make the molds in snap flasks or on the molding machine, and the molds would be made in green sand and the procedure identically the same as for cast iron. The sand is used as dry as convenient, and only sufficient clay is used in its composition to make it just stick together when squeezed or rammed.

As regards the ramming, this is probably the most important part of the business. It has to be done more carefully than for iron, and this I say advisedly, for the steel is much hotter and more searching, and will detect variations in hardness, with the result of cutting or scabbing. When a mold is dressed it is generally finished with flatheaded wire nails, which hold the sand together and cool the face of the casting slightly. The mold must be thoroughly well ventilated, both cope and drag. This is very important.

In making a core the idea is to produce a strong exterior and a weak interior. This is done by ramming up the core of some collapsible gravel or burnt sand mixed with oil or rosin, and then painted with a thick wash of Ceylon plumbago, silica flour and molasses water. Two or more coats may be advantageously given and dried in between. Cores should be almost but not quite burnt. These remarks, of course, refer to cores of some size. Small cores are not generally coated with wash.

Summing up, it may be said that there is very little difference between iron molding and steel molding except in details. The difference is chiefly in the different kinds of sand used, and the fact that almost all steel molds are thoroughly baked or dried. But there is an increasing tendency to make steel castings in green sand molds, and as sand mixing and composition become better understood this will be still more so. Iron molders make very good steel molders with a little practice and instruction. The conditions are the same, only accentuated. The temperatures are higher, and therefore more gases are generated, and we need more open sand and more refractory molds. The higher temperatures also cause higher pressures, calling for stronger molds. There is also a greater cutting action, due to the chemical composition of the metal. But the fact that there are being produced to-day in increasing quantities steel castings of magnificent appearance and satisfactory physical qualities shows

that the attention that is being given to the molding by our foundrymen is receiving its reward. **No. 445. A.**

Annealing of Steel Castings. Frederick H. Sexton. Transactions of the Mining Society of Nova Scotia. 7,000 w.; illustrated. — The investigation described in this paper was carried on as a graduating thesis in the Massachusetts Institute of Technology in the spring of 1901. The author first relates briefly the evolution of the steel castings industry and then describes his own experiments. The bars used measured $1\frac{1}{2}$ inches square and 18 inches long and were subjected to different annealing treatments in a small electric resistance furnace. They were then broken by tension and their structure examined. The steel contained .38 per cent carbon and .35 per cent of silicon, .65 per cent manganese, .038 per cent sulphur and .038 per cent phosphorus. The temperatures were measured by a Le Chatelier thermo-electric couple. The first step was to ascertain the critical points of the steel. The heat treatment was divided into four series. The first was to find the effect of simply heating to different temperatures, with slow cooling in the furnace; the second, the effect of definite temperatures sustained for about four hours with slow cooling in the furnace; the third, the effect of heating to definite temperatures with quick cooling in the atmosphere; the fourth, the effect of a complex heat treatment such as was practised upon the Terre Noire castings.

Six bars were heated slowly to temperatures 660°, 750°, 760°, 860°, 955°, 1060° C. respectively, the current shut off the furnace as soon as the right temperature was attained, and the bars allowed to cool slowly in the furnace for twelve hours.

Nine bars were heated at temperatures 650°, 700°, 760°, 765°, 770°, 900°, 1000°, 1100° and 1240° C. for about four hours and allowed to cool slowly in the furnace for twelve hours.

Three bars were heated to the temperatures 760°, 900° and 1100° C. respectively, and as soon as they had reached the right temperature were removed and allowed to cool rapidly in the open air.

Three bars were first turned down to one inch diameter for their entire length; they were then heated at 800° C. for one-half hour, quenched suddenly in water and finally annealed at

600° C. for one and a half hours, two hours and four hours respectively.

After annealing, each bar, except those in Series No. 4, was turned down to a diameter of $1\frac{1}{8}$ inches, for a distance of 10 inches in the center and broken in a 50-ton Olsen machine. From the results obtained the author draws the following conclusions: " From the foregoing experiments it would be strongly recommended that steel castings, of the kind experimented upon at least, should be heated to 1000° for such a time that the whole section would attain this temperature and then cooled by ' air quenching.' Small castings may be simply cooled in the air and large castings by means of the air blast. Such a treatment will give the castings the greatest tensile strength and elastic limit, and also as good ductility as the material is capable of acquiring. Such a heat treatment as is outlined above is not new. The properties given to the cast steel are probably due to sorbite. Stead and Richards have published an article describing their mode of treatment in producing ' sorbitic steel rails.' Boynton showed the effect of ' air quenching ' on a steel of .55 per cent carbon and more particularly on a high carbon steel with 1.11 per cent of carbon. He found that air cooling ' greatly increases the tensile strength and elastic limit,' but that the steel possessed less ductility."

Such a heat treatment even is not new with steel castings. After the above work of the author was completed, the following statements made by Sir W. C. Roberts-Austen were noted: " As one of the last important engineering works in a century, I may refer to the Alexander III bridge. It crosses the Seine in a single span, and 2,200 tons of cast steel have been employed in its construction. If the steel used in such a structure is heated to a temperature of 1000° C. and is ' quenched ' by rapid cooling in air to about 600°, the metal so treated becomes stronger, more elastic and resists shock better than if it has been annealed."

These experiments in the annealing of steel castings were carried out without a knowledge of the work of the others mentioned above. The publication of this paper is deemed justifiable because it gives the experimental details by which the conclusions were arrived at, and detailed data of this kind have not appeared elsewhere. **No. 446.**

Vanadium Steel for Motor Work. Alexander E. Tucker. Paper read before the Automobile and Cycle Engineer's Institute in Birmingham (England), abstracted in the "Iron Monger," December 2, 1905. — The author advocated the use of vanadium steel in the construction of motor cars, and dealt in details with the effect produced by the addition of a small percentage of vanadium to various qualities of steel. By the addition of 1 per cent to mild steel, free from phosphorus, the tensile strength was raised from 30 tons per square inch to 61.5 tons, while the elongation was reduced from 17 per cent to 14 per cent, and by similarly treating the same class of steel, after it had been carbonized, the tensile strength was raised from 61 tons to 69 tons, while the elongation was reduced from 23 per cent to 7.3 per cent.

Ordinary malleable iron of about 24 tons tensile and 19 per cent elongation could by the addition of .5 per cent of vanadium be given a tensile strength of 39 tons and an elongation of 12 per cent in the forged bar and of 37.7 tons and 32 per cent respectively when annealed. In addition to these results it was found that quenching hardened vanadium steels far more than it did ordinary carbon steels.

It had been found advantageous to alloy these vanadium steels with a small percentage of chromium. The effect of this combination in the proportion of 1 per cent of chromium and .15 per cent of vanadium was to raise the tensile strength of a plain carbo-manganese crucible steel from 27 tons per square inch to 48 tons, and to diminish the elongation from 35 per cent to 24; while an open-hearth steel of the same type similarly treated had its tensile strength raised from 32 tons to 52 tons, and its elongation reduced from 34 per cent to 25 per cent. The effect of the combination of these two constituents in a steel designed to resist torsion was most remarkable. Thus, a steel containing 1.06 per cent chromium and .169 vanadium, giving 52.6 tons ultimate tensile strength per square inch, gave a calculated shearing-stress of 40.3 tons per square inch and a torsional test of 1 628 degrees, or 4.52 complete turns before fracture. Another example of similar steel gave 1 786 degrees, or 4.96 complete twists before breaking; while a third sample, having practically the same tensility and elongation — *i. e.,* about 53 tons per square inch and 25 per cent elongation, with

a reduction of area of 55.5 per cent — was twisted through 360 degrees, and then bent double. The author believed that such properties in one and the same metal had not hitherto been approached. **No. 447. A.**

Vertical Blowing Engines. " The Iron Trade Review," December 21, 1905. 1,000 w.; illustrated. — One of the recent and noteworthy pieces of installation work is that of the 18 vertical blowing engines for the Tennessee Coal, Iron and Railroad Company, of Birmingham, Ala. These engines, designed and built by the Mesta Machine Company of Pittsburg, are of the long crosshead type especially adapted for the medium sized furnaces so widely used in the South. Twelve of the 18 engines are provided with high-pressure steam cylinders, while the remaining 6 have low-pressure cylinders. The high-pressure cylinder engines are of modern construction throughout, and entirely self-contained. With a steam pressure of 150 pounds per square inch, the engine is designed to blow air up to 30 pounds running at a speed of 50 revolutions per minute. The steam and air cylinders are arranged in vertical tandem, the former, 44 inches in diameter, with a 60-inch stroke, being mounted on a plate directly above the shaft, while the air cylinder, 84 inches in diameter, by 60 inches stroke, is supported above the steam cylinder, on frames or housings placed on either side of the steam cylinder, and rigidly bolted to the bed plate. **No. 448. A.**

Plant of the Algoma Steel Company, Sault Ste. Marie. " The Iron Trade Review," December 21, 1905. 4,000 w.; illustrated. — The Algoma Steel Company is a branch of the Lake Superior Corporation, which corporation controls practically all the industries at Sault Ste. Marie, Ontario. The plant was built in 1901, and commenced operation in the spring of 1902. It is thus one of the newest and most modern of all the steel plants in Canada. The principal production of the Algoma Steel Company is steel rails. The iron from which the steel is made is smelted in two blast furnaces at the plant and then proceeds in almost a straight line through the steel works and rolling mill until it comes out a finished product at the other end. **No. 449. A.**

By-Product Coke in the Blast Furnace. *Furnaceman,* "The Iron Age," December 21, 1905. 1,500 w. — The author advocates the use of by-product coke in the blast furnace, and concludes as follows: " The above shows what a decided factor sulphur is in the cost of pig iron. The by-product coke oven is here to stay, and when it is adopted and the coal is properly washed to free it of sulphur and ash, the 600-ton furnace will be more common than is the 500-ton furnace to-day, and better iron and consequently better steel will be made. **No. 450. A.**

The Menominee Iron Range. John L. Buell. Paper read before the Lake Superior Mining Institute. Abstracted in " Engineering and Mining Journal," December 23, 1905. 2,000 w. — **No. 451. A.**

Notes on American Blast-Furnace Practice (Betrachtungen über den Amerikanischen Hochofenbetrieb). Bernhard Osann. " Stahl und Eisen," October 15, 1905. 3,000 w. — The author compares American and German methods. **No. 452. D.**

Practical Results in the Working of the Blast Furnaces of Ekaterinoslav (Résultats Pratiques de la Marche des Haut Fourneaux d'Ekaterinoslav). " Revue de Métallurgie," September, 1904. 10,000 w.; illustrated. — A critical discussion of the results obtained with furnaces of various sizes and shapes. **No. 453. D.**

The Two Conditions of Carbon in Iron; Temper Carbon and Graphite (Beiträge zur Kenntnis der Zwei Kohlenstofformen im Eisen, Temperkohle und Graphit). F. Wüst and C. Geiger. " Stahl und Eisen," October, 1905. Serial, Part I, 3,200 w. — The authors discuss the influence of heat treatment upon the condition of carbon in cast iron. **No. 454. D.**

Chemical Reactions in the Combined Bessemer Open-Hearth Process at Witkowitz (Chemische Vorgänge beim Kombinierten Bessemer-Martin Verfahren zu Witkowitz). C. Canaris. " Stahl und Eisen," October 1, 1905. 2,000 w. — The author describes the character of the charges and of the products. **No. 455. D.**

The Use of Blast-Furnace Gas for the Reduction of Iron Ore in Modern Open-Hearth Steel Processes (Hochofengase zum Reduzieren von Eisenerz für die Neueren Herdofenstahlprozesse). Oskar Simmersbach. — The author discusses chiefly the reduction of iron ore by carbon monoxide. **No. 456. D.**

METALLURGICAL NOTES AND COMMENTS

Sir C. William Siemens. — Sir C. William Siemens (see frontispiece), best known to metallurgists through his invention of the regenerative furnace and the important part he took in successfully manufacturing steel in such furnace, was born in Lenthe, Hanover, Germany, April 4, 1823, and died in London, November 19, 1883. He was educated at the gymnasium of Lübeck, at the Polytechnic School of Magdeburg, and at the University of Göttingen. At nineteen he became a pupil at the engine works of Count Stolberg, and a year later visited England to introduce a method of electro plating, the joint invention of his brother Werner and himself. In the same year the brothers Siemens invented a differential governor for steam engines, and in 1844 William Siemens again came to England to patent it. From that time he resided in England and became naturalized in 1859. He was made a member of the Royal Society in 1862, and at one time was president of the British Association. In 1875 he was awarded the Bessemer Gold Medal; he was president of the Iron and Steel Institute from 1877 to 1879, and was knighted in 1883.

Corrosion of Steam Boilers.* — Among the causes of the deterioration of steam-boiler plates one of the most insidious is the corrosive action to which may be attributed the grooving and furrowing so frequently observed in cases of failure. The manner in which these injurious and weakening grooves are formed has been a matter for discussion for a long time, and no very satisfactory theory has been advanced to account for the peculiar way in which corrosion appears to produce furrows as deep and straight as if they had been produced by a cutting tool.

In a recent issue of the " Revue de Métallurgie " this question is examined by MM. Frémont and Osmond, and the extent

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*" Engineering Magazine," December, 1905.

to which their views agree with the results experienced in prac-
tice renders their discussion an important contribution toward
the solution of this obscure problem.

When a sheet of iron or steel is exposed to the action of air
and moisture it becomes oxidized more or less rapidly. This
oxidation is effected principally by the carbonic acid which is
present, since the free oxygen which may be present has only
the power to raise to a higher degree of oxidation any protoxide
which may be already in contact with the metal. Since the
various conditions of temperature, pressure, chemical composi-
tion, etc., remain constant in the case of a given boiler, any
irregularity of the rate of corrosion must be sought in the original
variations in the structure, or in the unequal conditions depend-
ent upon construction or service of the various parts. In general,
the irregularities in corrosion of boiler plates may be divided
into two classes, pitting and grooving. The isolated regions of
corrosion known as pittings consist of separate cavities, appar-
ently due to independent causes, although occasionally uniting
or merging into one another as their area is extended. Grooving,
on the contrary, consists of distinct and continuous furrows,
resembling the scoring effects of a cutting tool, this action being
generally observed along seams or other parts of the boiler which
are subjected to flexure in consequence of the stresses caused
by service.

There is no doubt that the origin of these forms of corro-
sion may be partly attributed to the condition of the metal due
to the treatment received in the course of manufacture. There
are also various shocks and effects of fatigue under pressure which
must be taken into consideration, and the manner of corrosion
is undoubtedly influenced by all of these considerations.

Local pitting is probably caused, in most instances, by local
variations in the constitution of the material, the presence of
sulphur, manganese, slag, etc., forming points of attack which
yield more readily to the action of the acid than do the homo-
geneous portions of the metal. Probably the lack of homo-
geneity also permits the formation of local electrical currents,
facilitating an electrolytic action of more or less definite character.

The peculiar action of grooving, however, demands another
explanation, and it is to this subject that the paper of MM.
Frémont and Osmond is devoted. The noticeable feature about

grooving in steam boilers is its localization, so to speak.   The furrows are generally found running parallel and close to the riveted seams, and as long ago as 1863, in the report of the Manchester and Midland Boiler Association it was described in this significant manner: " Furrowing along a seam of rivets, or rather under the line of an overlap, is found to be the usual malady."

This localization of the furrowing action leads to the idea that it must be connected in some manner with the structural details of the boiler, in connection with the conditions of its operation.   In general, observations upon furrowing in boilers show that this effect appears in nearly every case at places where there is a change in the thickness or strength of the material, or where, from the form of the parts, there is a localization of surface stress.   Following out this lead, MM. Frémont and Osmond have shown a very reasonable explanation for the manner in which grooved corrosion is produced.

Under ordinary conditions, with a uniform and homogeneous material, the oxidation of a metal plate should proceed uniformly over the entire surface, covering it with a layer of oxide of equal and continually increasing thickness.   In a steam boiler, however, there are conditions which prevent this uniform action.   A boiler is subjected to varying pressures and stresses, and these cause continually changing flexures and deformations of the various parts.   A flue or shell, riveted up of plates, is not truly cylindrical, however carefully it is made, and the notable departures from true circular section appear at the riveted seams, where the lap of the plates and the thickness of the metal occur. Even with butt joints and cover plates there is a marked change in thickness of metal at the seams, and the same is true, although to a smaller degree, with welded seams.   As a consequence of these structural requirements, the flexure stresses in the plates are greatest at or near the seams, and although this localization of stress is not extreme, it is frequently repeated.

When, therefore, the interior of a boiler becomes covered with a thin layer of oxide, this layer is not permitted to remain as a continuous coating, but is broken or cracked at the points which are subjected to the greatest stresses and flexure, the oxide itself being very brittle and almost wholly incapable of resisting deformation.   These cracks and fissures in the general

layer of oxide uncover surfaces of clean metal, permitting renewed and vigorous action of the corrosive elements present, and a slightly deeper effect is produced along the line of the break in the oxide. Like many other actions, this tends to extend itself, since the first localization of the corrosion renders the metal slightly weaker along the line of its direction, rendering the next flexure still more sharply defined in the same place, and causing a fresh surface of metal for corrosion to be exposed, so that the furrowing action continues indefinitely.

This theory is found to be fully sustained when the portions of the sheets under consideration are subjected to microscopic examination. In the paper of MM. Frémont and Osmond there are given reproductions of a number of microphotographs, all tending to confirm the fact that any action which produces unequal surface stress is liable to cause increased oxidation, in the form of grooving and furrowing.

MM. Frémont and Osmond refer with commendation to the paper of Messrs. Houghton and Rogers, recently presented before the Iron and Steel Institute, but show that their own work was done before this latter communication was made public, both series of investigations, however, agreeing in the main as to the causes of the action under consideration.

The Use of Ammonium Persulphate in the Determination of Chromium in Steel.* — Ammonium persulphate is used as a regeant for oxidizing chromium in steel in a method described by F. Ibbottson and R. Howden (" Chemical News," Vol. LXIX, pp. 320–321). After oxidation the chromium is precipitated as lead chromate, filtered and determined volumetrically.

The writer has been using a method for some time in which the same salt is used, advantage being taken of the fact that in the presence of sufficient silver nitrate both the chromium and manganese are completely oxidized and can be determined volumetrically without previous precipitation. The method as outlined is applicable for ordinary chrome steels, but not for tungsten or molybdenum steels, as some of these steels contain a carbide of chromium insoluble in sulphuric acid. This difficulty can be overcome by filtering the insoluble carbide, burning

*Harry E. Walters in " Proceedings of Engineers' Society of Western Pennsylvania," December, 1905.

and fusing with a small amount of sodium carbonate and adding to the main solution. This, however, would prolong the operation but would still be an advantage over the methods now in use.

Method. — Weigh 1.25 grams of the sample into a No. 3 Griffin beaker, add 35 cc. sulphuric acid (1 acid to 5 water), warm until sample is in solution and add a small amount of ammonium persulphate to oxidize the iron and carbonaceous matter, dilute to 100 cc. and add 40 cc. silver nitrate solution (.16 gram of the salt); now add an excess of ammonium persulphate (5 to 7 grams) and heat to boiling. Boil about five minutes to destroy excess of persulphate, cool and transfer to a 500-cc. calibrated flask, dilute to mark with water and mix thoroughly.

Pour 100 cc. (.25 gram) into a 100 cc. calibrated flask; the remaining 400 cc. (1 gram) are transferred to a beaker, a measured volume of ferrous sulphate added, and the excess titrated with a standard solution of permanganate until a pink color is obtained.

The number of cubic centimeters of the permanganate solution used subtracted from the number required for the volume of ferrous sulphate added, will give the volume of permanganate used by the chromium and manganese.

The contents of the 100-cc. calibrated flask are transferred to a porcelain dish and titrated with a standard solution of sodium arsenite until the color is bright yellow. The number of cubic centimeters of the arsenite solution used, multiplied by the value of the solution in manganese, will give the amount of manganese present.

The volume of permanganate used by the chromium is found by calculating the amount of manganese found to the equivalent number of cubic centimeters of the permanganate solution and subtracting this number from the volume of the permanganate used by the chromium and manganese. The number of cubic centimeters found to be used, multiplied by the value of the permanganate in chromium, will give the amount of chromium present.

Example. — Let us assume that the chromium value of each cubic centimeter of the permanganate solution equals .001 gram, and the manganese value .000633 gram; now, if

50 cc. of the ferrous sulphate solution equals 49 cc. of the permanganate solution, and the sample after oxidation and addition of 50 cc. of the ferrous sulphate solution requires 13 cc. of the permanganate solution, then 49 cc. minus 13 cc. equals 36 cc., or amount used by chromium and manganese.

If the sample should show .38 per cent manganese by the arsenite titration, then .0038 divided by .000633 equals 6, or the number of the cubic centimeters of permanganate solution equivalent to the per cent of manganese found.

Thirty-six cc. minus 6 cc., or 30 cc. multiplied by .001 equals .03 gram or 3 per cent chromium.

Reagents. — Sulphuric Acid. — A mixture of one part concentrated acid and five parts water.

Silver Nitrate. — Four grams of the salt are dissolved in one liter of water.

Ammonium Persulphate.—The salt should be slightly moist.

Sodium Arsenite. — The solution is prepared as recommended by Blair (Chemical Analysis of Iron, fifth edition, p. 121). The solution is standardized with a chrome steel of known manganese content, so that the direct reading will give the percentage of manganese. Mixtures of pure chromium and manganese solutions may also be used.

Permanganate Solution. — The solution is made by dissolving 1.82 grams of pure potassium permanganate in 1 liter of water.

Ferrous Sulphate Solution. — The solution is made by dissolving 22.5 grams ferrous ammonium sulphate in water, adding 50 cc. strong sulphuric acid and diluting to 1 liter.

It is unnecessary to have this exactly equal the permanganate solution, as a constant volume is used and the solution loses its strength. It is only necessary to find the volume of permanganate equivalent to the volume of ferrous sulphate used, and this should be done every day.

The permanganate may be standardized by getting the iron value or by the use of a pure chromium salt.

If the solution is standardized against iron the chromium value is found by the equation

$$168 : 52.14 : : \text{iron value} : \text{chromium value};$$

and the manganese value by the equation

$$280 : 55 : : \text{iron value} : \text{manganese value}.$$

If the solution is standardized with pure chromium salt the manganese value is obtained by the equation

260.7 : 165 : : chromium value : manganese value.

REMARKS

In case the samples should run high in chromium the ferrous sulphate solution could be made stronger.

The permanganate solution should be allowed to stand several days before standardizing.

In case an appreciable amount of vanadium is present in a sample, it will be necessary to determine the manganese by the bismuthate or Ford's method.

The moist ammonium sulphate is recommended on account of difficulties encountered when using the dry salt in determining lead and manganese in previous work. These difficulties were surmounted when the moist salt was used.

In using the method for tungsten steels some tungstic acid separates, but this does not seriously interfere with the titration.

The following results were obtained on some chrome steels and pure solutions of iron, chromium and manganese.

Number	Per Cent Chromium Taken	Per Cent Found	Per Cent Mang. Taken	Per Cent Found
1	4.00	3.98	0.08	0.09
2	4.80	4.82	0.40	0.40
3	1.56	1.53	0.24	0.23
4	3.60	3.57	0.80	0.81
5	5.10	5.12	0.50	0.49
6	8.00	8.03	0.32	0.32

Steels	Per Cent Chromium	Chlorate Method, Per Cent Mang.	Per Cent Chromium	Persulphate Method Per Cent Mang.
1	1.50	0.35	1.51	0.36
2	2.88	—	2.85	0.14
Tungsten	3.50	0.12	3.49	0.13
Molybdenum	5.69	0.81	5.71	0.83

I wish to acknowledge my indebtedness to Mr. T. D. Rodgers, of this laboratory, for the careful manner in which he has carried out these experiments.

Ores Determine Steel Processes.* — Editorial comment is made in a foreign contemporary on the rapid growth of basic

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* "The Iron Trade Review," December 14, 1905.

steel manufacture in recent years in various countries, but a somewhat distorted view of the compelling conditions is taken as regards the relative employment of the open-hearth and Bessemer processes. In Germany two thirds of the basic steel is made in the Bessemer process, while in the United States all the basic steel is made by the open-hearth process. Throughout this comment runs the strain that the employment of the Bessemer or open-hearth process is a matter of choice rather than of necessity. Indeed, the statement is directly made that " in the United States there is a greater variety of ores available for both purposes than in any other country," and this is followed by the statement that American practice must be based on the " belief that the open-hearth process lends itself in a special degree to the production of basic steel."

This conclusion is really somewhat wide of the mark. The basic open-hearth process is used in the United States not as a matter of choice, if basic steel is to be made at all, but because the commercially available ores are not admissible to any extent for the employment of the basic-Bessemer process. A large percentage of phosphorus is necessary in basic-Bessemer work to furnish the heat, which must be greater than with the acid-Bessemer process, on account of the slag, and cannot be furnished to any extent by silicon, which attacks the lining. Campbell states, for instance, that in most basic-Bessemer work the iron contains more than 3 per cent of phosphorus, and intimates that it would require important changes in practice to permit the employment of iron " considerably " below 2 per cent. Of all the Lake Superior ores now mined there is but one whose phosphorus content exceeds 1.31 per cent of the iron content, and there are but three which show more than 1 per cent. There is no hint of any important unworked deposits of highly phosphoric ores in Lake Superior regions. Those of the Virginia and Alabama ores which are comparatively high are still much below the practical limit for basic-Bessemer work. A part of the Adirondack ores run from 1.35 to 2.25 per cent in phosphorus and 60 per cent in iron, but compared to the total ore supplies of the country these are unimportant, and are reduced in phosphorus by magnetic separation.

Germany is driven to the use of the basic-Bessemer process almost exclusively for basic steel, because the ores available

require it. In England basic steel is made about equally by the Bessemer and open-hearth processes. In Russia and Belgium the open-hearth predominates, and in the United States it is supreme for the manufacture of basic steel. In all these cases the ores, and not the preference of manufacturers, determine the process employed. The alignment in the three principal steel-making countries is as follows, using the statistics of 1904, in metric tons for Germany and gross tons for the other two countries:

STEEL INGOT PRODUCTION, 1904

GERMANY

	Basic	Acid	Total
Bessemer	5,525,429	423,742	5,949,171
Open-hearth	2,697,760	130,546	2,828,306
Total	8,223,189	554,288	8,777,477

GREAT BRITAIN

	Basic	Acid	Total
Bessemer	652,309	1,129,224	1,781,533
Open-hearth	662,064	2,583,282	3,245,346
Total	1,314,373	3,712,506	5,026,879

UNITED STATES

	Basic	Acid	Total
Bessemer	....	7,843,089	7,843,089
Open-hearth	5,007,448	597,884	5,605,332
Total	5,007,448	8,440,973	13,448,421

In Germany the production of acid open-hearth steel has remained practically stationary; in England it has decreased. In the United States also it has decreased, the 1904 production being the smallest since 1898, and this is particularly significant since, on account of the rapid general growth, even a relatively decadent branch of manufacture in the United States may show an increase in tonnage. It is pretty evident that the process has no great vitality as a tonnage proposition. The very fine grades of steel made by it and which have to a certain extent replaced crucible steel, are not tonnage makers. The acid open-hearth process yields to the acid Bessemer process. It does not yield directly to the basic open-hearth, nor is there much disposition in the United States for the Bessemer to yield to

the basic open-hearth. There has been in the past few years a limited amount of pig iron under the Bessemer limit in phosphorus which has been used in the basic open-hearth furnace, but the practice has not become general and is not likely to. The prediction of the late Mr. A. L. Holley, that the open-hearth process will one day attend the funeral of the Bessemer process, will never be fulfilled in the sense intended. The ores which are low enough in phosphorus to require no reduction in the process of steel making will find their way into steel through the acid Bessemer process and through no other. The ores which are higher in phosphorus will find their way into steel through the basic open-hearth process when their phosphorus content is not very large, and when it is, they will go through the basic Bessemer process. There is not, and will not be, any material latitude for choice between the basic open-hearth and the basic Bessemer processes; the phosphorus will decide. Nor will it be possible to introduce the element of choice, not by choosing the process after the ores, but by first choosing the ores and thus determining the process, for the reason that iron ore is already scarce in a commercial sense, the rich deposits, not too far removed from fuel and markets, having a high value in the ground. All the ore from which iron can be cheaply made and marketed will be used. If the open-hearth process ever attends the funeral of the Bessemer it will be because the ores for the latter, which must be either very high or very low in phosphorus, will have been exhausted.

In the United States the evidence is quite clear that the Bessemer process will not last longer than a few decades, when the present Bessemer ore reserves will have been exhausted, unless further large deposits are discovered. The present known deposits of ores suited to the basic open-hearth process will permit of production along this line continuing its rapid increase of the past few years, and the process outliving the Bessemer, while the trend of new exploitation of ores in the past few years has been towards increasing the known reserves of basic more than of Bessemer ores. For instance, the whole southern steel industry is based upon ore deposits which contain no Bessemer at all.

Two or three years ago it became evident that the American basic open-hearth steel industry, as at first established, could

not indefinitely continue its rapid growth without important changes. From only 776,256 gross tons of ingots and castings in 1896 the production grew in half a decade to 3,618,993 gross tons in 1901, and last year the 5,000,000-ton mark was passed. In the earlier years large percentages of old material were used, and it was the cheapness of such old material which so greatly encouraged the early industry. The supply could not grow with commensurate rapidity, and the fact was first discussed in these columns on April 17, 1902, when the 1901 statistics had become available. The solution of the problem has been that the basic open-hearth steel process, having such inherent vitality, has been content to stand a somewhat higher relative manufacturing cost through the use of a greater percentage of pig iron, has developed some special processes which do not involve the use of scrap at all, has been paying a higher relative price for old material and has, last but not least, had scrap made for it by liberal and almost reckless cropping. A third of an ingot is frequently cropped, conducing to better quality in the finished product, and furnishing scrap for the open-hearth furnace. The cost of melting and casting is not high, and an endless chain runs from the furnace to the shear and back again. In this connection it is interesting to note that for the year 1904 the American Iron and Steel Association for the first time presented separate statistics of all rolled steel products, and the total, compared with the statistics of production of steel ingots, excluding all castings, showed that for every 100 pounds of ingot production reported, there was less than 76 pounds of rolled steel reported. There is no doubt that the need of scrap, and the scarcity of old scrap, has had an important influence in making the gap so large. What will be done as the Bessemer process steadily decreases its proportionate contribution of scrap is for the future to decide. The basic open-hearth steel industry has shown such remarkable flexibility in methods in just a few years that it can be expected to solve all problems that may be presented.

Growth of the Pittsburg Open-Hearth Steel Trade.* -— The extraordinary activity in the steel trade is reflected in the unusual movement of old material from Chicago to the Pittsburg district,

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* " The Iron Age," November 30, 1905.

where the present outcome of heavy melting scrap is insufficient to meet the requirements of the basic open-hearth steel works. The diversion of this material is not without precedent, as heavy shipments were made from that great Western scrap center several years ago to relieve an acute shortage at Pittsburg. A spread of $3 a ton in the values at these respective centers is necessary to overcome the freight and to make this movement possible and profitable, and this differential in values has just come about. An intercompany shipment of 5,000 tons between United States Steel Corporation constituents, made several weeks ago before this spread existed, caused considerable comment at the time and foreshadowed the shortage of this material in the Pittsburg district. Not since the early months of 1903, preceding the tremendous slump in iron and steel values that year, have the requirements of the Pittsburg steel works exceeded the normal outcome of heavy melting steel in that territory, nor has the spread in values, as compared with Chicago, exceeded $2 a ton up to the present. As there is no fixed relation between the use of scrap and pig iron in the open-hearth furnace, any temporary shortage of scrap at Pittsburg has been frequently overcome by increasing the proportion of pig metal, but the scarcity of the latter now prevents this practice, and to meet the demands of the trade an increased quantity of scrap is required. On the other hand, the proportion of scrap used in basic open-hearth practice in the West has always been greater than at either Pittsburg or in the East, due to the greater spread between old material and basic metal at Chicago.

The present shortage at Pittsburg is hardly more than temporary, but considering the tremendous growth of the open-hearth steel industry in that district, it would seem that a point would be reached in the not distant future when the supply of scrap will be insufficient to meet the current demand, and that other processes of steel making will have to be developed in which the use of old material is obviated. The development of the Talbot furnace is a step in this direction, and it was largely to cope with such a future situation that one Pittsburg steel producer has been expanding in this direction.

Since 1898, Allegheny County, in which Pittsburg is situated, has been producing about 47 per cent of the country's total open-hearth steel output. The growth of this branch of

the steel trade in the West has, however, failed to keep pace
with the rest of the country, although it would seem that its
relative expansion in the Chicago district would exceed that of
any other section of the country on account of its almost un-
limited scrap resources.   A comparison of the growth of the
country's open-hearth steel production with that of Bessemer,
as well as the great strides made by open-hearth steel in Alle-
gheny County, is given below:

	Percentage of total open-hearth and Bessemer steel production in the United States		Percentage of total open-hearth and Bessemer steel production in Allegheny County	
	Open-hearth	Bessemer	Open-hearth	Bessemer
1898...............	25	75	31	69
1899...............	28	72	36	64
1900...............	34	66	40	60
1901...............	35	65	43	57
1902...............	38	62	45	55
1903...............	40	60	49	51
1904...............	43	57	52	48

It will be seen by this table that in the country as a whole
the open-hearth steel industry advanced from 25 per cent of
the combined open-hearth and Bessemer output in 1898 to 43
per cent in 1904.   In Allegheny County a more rapid rate of
progress by the open-hearth industry is shown.   Whereas in
1898 only 31 per cent of the combined output of these two classes
of steel was open-hearth steel, in 1904 it had grown to 52 per
cent, or more than half.

The Engineering Building. — The public competition insti-
tuted by the Joint Committee for the selection of architects for
the planning and erection of the buildings presented by Mr.
Andrew Carnegie for the American Institute of Electrical
Engineers, the American Society of Mechanical Engineers, the
American Institute of Mining Engineers and the Engineers' Club,
resulted in the presentation of twenty-six sets of plans for the
building.   After a careful examination of these plans, the com-
mittee appointed Messrs. Hale and Rogers and Henry G. Morse,
associate, architects, for the three engineering societies, and
Whitfield & King, architects, for the Engineers' Club.

The frontage of the Engineering Building on 39th Street,
between Fifth and Sixth avenues, covers five city lots, or 125
feet front and 100 feet deep.
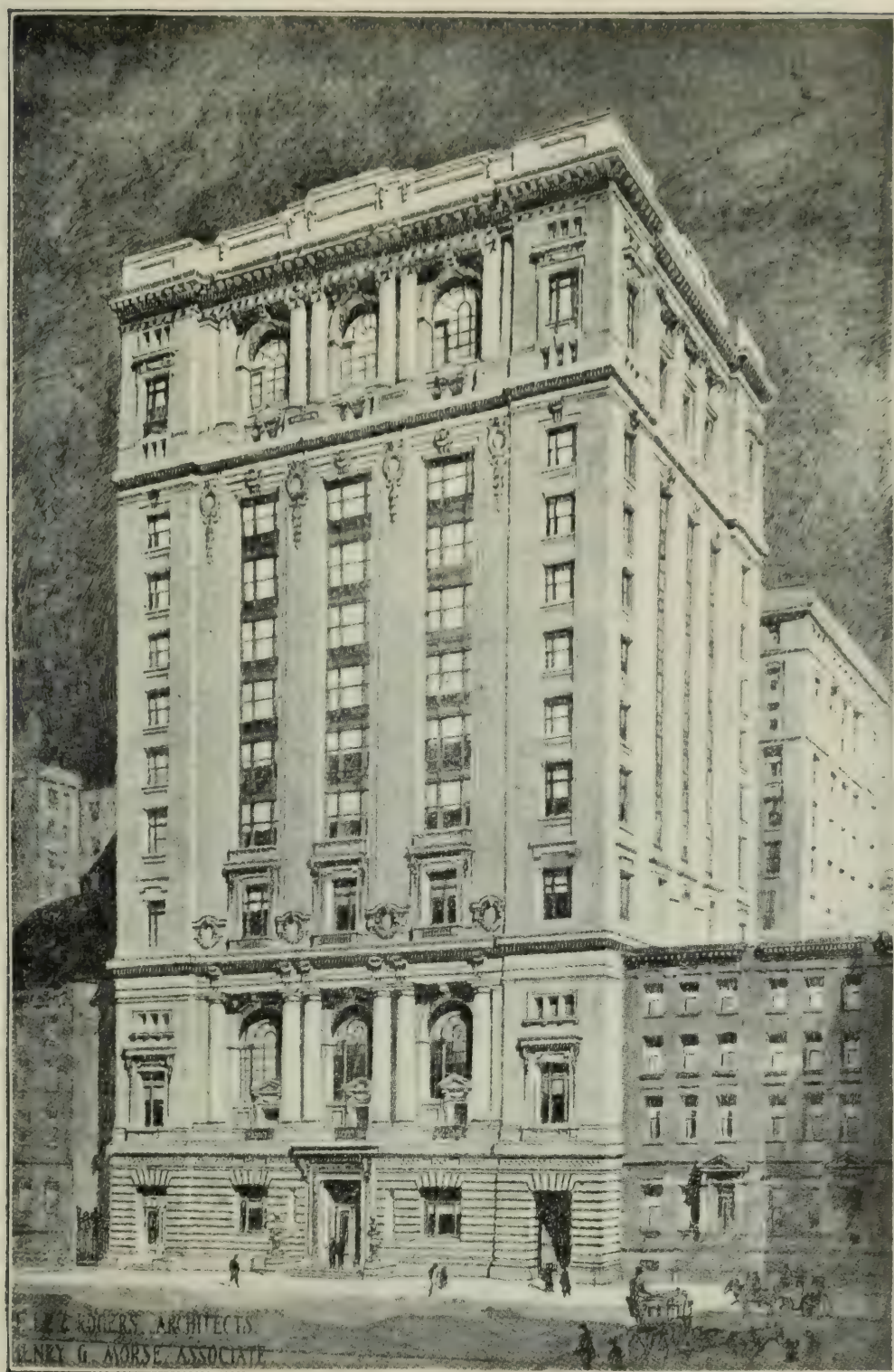
The contract for construction was signed in July, the
excavation for the foundations was started at once and the

work of construction has now commenced.   The contract limit is fifteen months to date of expected completion.

Carnegie Steel Company's Steel Tie. * — The manufacturers' exhibit at the International Railway Congress held at Washington last May developed considerable interest in improved cross ties.   The growing scarcity and consequent increase in the price of wooden ties have caused the railroad managements to resort to methods by which they could overcome this tendency, and for the past twenty years experiments have been made with various types of metal and concrete ties, the most of which have proven failures.

Six years ago, steel ties made with a 4-inch I-beam, having a plate $4\frac{1}{2}$ inches wide riveted on the top, and one 8 inches wide on the bottom, were placed in the tracks of the L. S. & M. S., at Sandusky, Ohio.   These ties still remain in the track, and an examination made a short time ago developed the fact that there has been no corrosion; in fact, the edges of the sheared plates have not been attacked and are as plainly defined as if sheared recently.

At the time the examination was made, it was observed that wood ties which were placed in the track at the same time as the steel ties, had decayed and were being replaced with new ones.   The Carnegie Steel Company followed this experiment with the installation of several lots of ties rolled in the same shape, around its works and on the Bessemer & Lake Erie Railroad.   While these ties were put in by the regular track force, with no special supervision, the results were sufficiently satisfactory to warrant an additional installation, and the Bessemer & Lake Erie Railroad has, during the year, used 25,000 at various points on its line where it was most difficult to maintain the track.   Between Euclid and Queen Junction, a distance of about five miles, the southbound main track is entirely equipped with these ties, and it is without doubt the most perfect piece of track on the road.   While the curves are sharp, a train running at a speed of 55 miles per hour is handled as comfortably as if on tangent.   The noise is more subdued than on wooden ties, the gauge is uniform throughout and the surface and line can be maintained with less labor than needed on wood ties.

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* " The Iron Trade Review," December 21, 1905.

It also develops that the wear of the rail is uniform. This road contemplates putting down 60,000 of these ties in 1906.

These ties have been in use on the Pennsylvania lines at Emsworth Station, near Allegheny, on the westbound passenger track, and are giving very good results. The insulation required by the automatic signals gave some trouble in the spring, due to imperfections, but this trouble was soon corrected by placing wooden blocks under the rails, and fiber bushings and washers around the bolts. We have reproduced a photograph showing condition of this track ready for winter, which shows it to be the best in the vicinity.

On account of the difficulty in holding track in line when
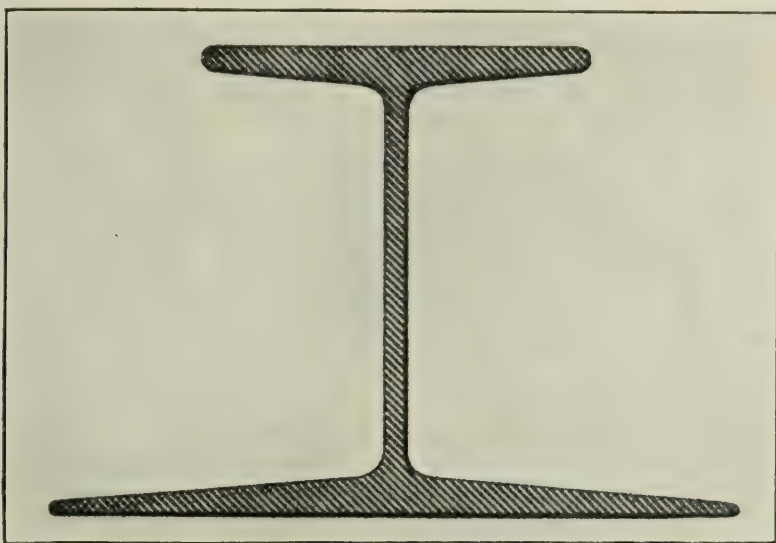
experiments were made with the English trough sections, it was feared the steel tie would be a failure, but the recent experiments with the Carnegie I-beam section with indentations in the base have proven that the fears were groundless.

The steel tie has, therefore, made more progress in the last two years than any other type of improved tie. Permanent as well as economical construction is demanded. The permanent feature has been developed, and a few more years will prove conclusively that steel tie construction is economical. Street railways are rapidly developing new methods of constructing their tracks in the busy city streets.

The Cleveland Electric Railway, during the summer, laid 600 Carnegie ties in concrete, and is very much pleased with

the construction. The Manufacturer's Railway of St. Louis has installed this same section in a number of switches, with good results.

Physical tests of the tie show that a load of 170,000 pounds can be placed upon it before there is any sign of failure. A test of the fastening was recently made by mounting a rail on the tie and standing it on end, applying the load vertically. It was found that with 17,500 pound load the top flange began to buckle, permitting the rail to release itself. A similar experiment with a rail spiked to an oak tie with two spikes showed failure with a load of but 4,700 pounds, and with four spikes holding the rail failure occurred at 12,500 pounds. Physical, as well as practical, tests thus far are very favorable.

The steel cross tie that the Carnegie Steel Company is offering, is rolled in the form of a modified I-beam $5\frac{1}{2}$ inches deep, 8 inches lower flange, $4\frac{1}{2}$ inches upper flange, which can be cut to any length.

It weighs 19 4-10 pounds per foot. There are four holes punched in each end of the tie at one operation by means of twin punches, thereby insuring accuracy in gauge. The outer group of holes provide for the joint fastening and the inner group for intermediate.

The fastening is made by means of four $\frac{3}{4}$-inch bolts and four rolled steel clips, which fit accurately to the base of the rail.

The crimping in the bore six inches from the end of the tie is done at the same time as the punching, and serves as an anchor to hold the truck from getting out of line.

Apparatus for Making Steel.* — Edwin C. Wills has patented an invention for the use in the manufacture of steel, which relates particularly to the construction of the converter and the means for operating its several parts, and for admitting air in the use of the apparatus. The inventor provides a converter having an upper or dome section and a lower or ladle section and means for connecting the dome section with the ladle section, the two sections being conveniently disconnected when desired. The dome section is supported on trunnions, so that it can be readily turned to or beyond the horizontal position or to any position between the same and the upright position, and

* "The Iron Trade Review," December 21, 1905.

tuyères being provided on the dome section and the ladle section, so that air may be introduced to either the ladle or dome section, or both, as desired. The converter may be tilted to discharge the metal from the nose of the dome section, or the ladle section may be detached from the dome section and moved to any desired point and the metal discharged directly from the ladle. The dome section has a tuyère 1 at one side which has a wind
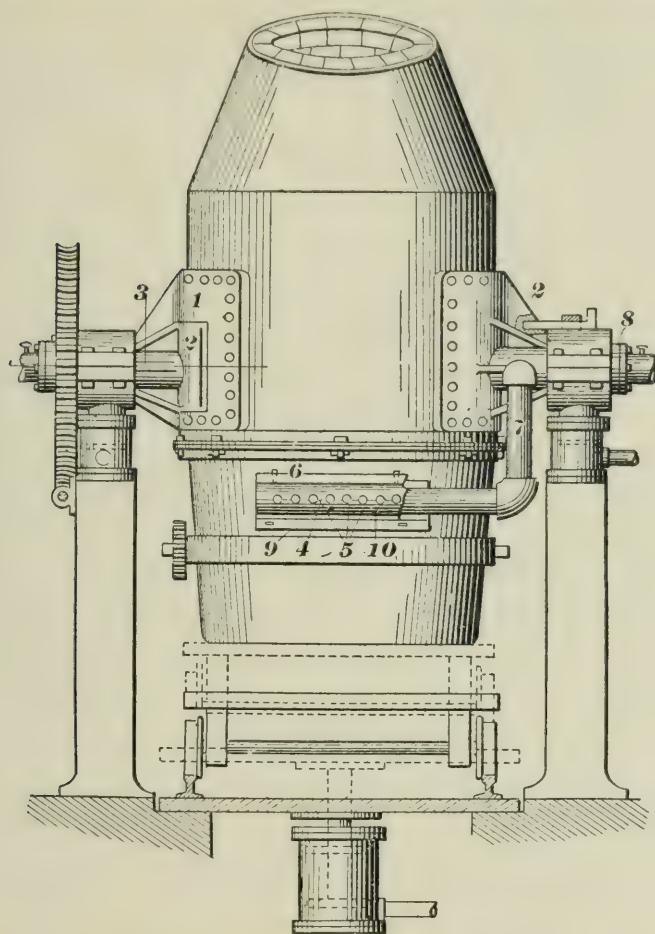
box 2, to which air is discharged through the hollow trunnion 3. It is provided with numerous tuyère openings, discharging to the interior of the dome section. By this construction it will be noticed that air may be supplied to the dome whenever desired. The ladle section is provided with a tuyère 4 near its upper end, and has a wind box provided with tuyère openings 5. The wind box is adapted for connection with the coupling head 6, which is secured to the pipe connection 7, leading to the hollow trunnion 8, through which air is supplied to the tuyère of the ladle

section. As shown, the wind box is open at its outer end, and is provided at this end with an upturned flange 9 at its upper edge. The coupling plate 10 is adapted to close the outer end of the wind box, arranged at its outer edge, and to fit in the hooked flange at the base of the wind box, and provided at its upper edge with an inwardly projecting wing overlapping the upwardly projecting flange of the wind box. It is held in place by means of keys by which the coupling head may be secured to the wind box when the parts are applied. The pipe connection 7 is secured at one end in connection with the hollow trunnions 8, preferably by threading it therein. Its other end is connected with one end of the coupling head 10, preferably also by threading it so that when the parts are applied and it is desired to disconnect the coupling plate from the wind box, it is only necessary to raise the coupling head out of engagement with the wind box by swinging the pipe connection on its joint, and when the parts have been disconnected the coupling head may be permitted to swing down, the pipe connection turning at the joint next the trunnions.

Iron Industry in South Africa.* — Americans, under the title of "The Transvaal Iron and Steel Company," are attempting to develop an iron and steel industry at Zurfontein, midway between Pretoria and Johannesburg, on the South African railroad. A large ore deposit has been acquired which will be utilized in the manufacture of steel rails, provided that a supply of suitable coke can be obtained; that now derived from Natal is not satisfactory. For the present the company will confine itself to the making of bar and angle iron, small rails and light pieces from iron and steel scrap, a 5-year supply of which has been optioned from the surrounding mines at prices in no case exceeding $5 per ton. The high price of imported material, paying ocean freights of $6 to $7.50 and railroad rates of $25 to $28 per ton, offers the best inducements to the new enterprise.

It is proposed to build a $100,000 plant, capable of turning out 20 tons per 10 hours, which will comprise 9-inch and 14-inch rolling mills, a plate mill and a sheet mill with accessory galvanizing and corrugating machinery. A Siemens-Martin furnace and a steam-hammer forging shop will complete the plant.

*"Engineering and Mining Journal," December 10, 1905.

REVIEW OF THE IRON AND STEEL MARKET

While December is ordinarily a quiet month in the iron and steel trade, the activity in the month under review was continued almost until the holidays. Specifications on old contracts have been very heavy, and there seems to be no doubt that the enormous tonnage ordered in the closing months of 1905 will all be taken out.

There have been no important changes in prices. Every effort is being made by the large interests to hold the market at the present level, as the dangers of high prices curtailing consumption and precipitating a slump are well understood. With the market kept on an even keel it is felt that the present prosperity may be prolonged beyond the period in the booms of 1899 and 1902.

Pig Iron. — Pig iron is about 25 cents higher at Philadelphia and Chicago than at the time of last report. At Pittsburg Bessemer and basic are on about the same level, while foundry and gray forge are 25 to 50 cents higher. Southern iron is a trifle weaker, some furnaces having a lower rate to the north than has Birmingham, being willing to give the advantage to the customer, whereby sales at $14.50, furnace, are equal to $14.00 or $14.25, f. o. b. Birmingham. Transactions have not been very heavy in foundry and forge grades, the advances, where they have come, being due simply to furnaces being sold up. In Bessemer iron there has been a heavy movement. The Cambria Steel Company took 60,000 tons of Bessemer and basic for first half, subject to monthly price adjustment. The Lackawanna Steel Company bought 25,000 tons of Bessemer from furnaces east of the mountains, and two or three other concerns have bought fair-sized tonnages. The United States Steel Corporation is negotiating for all the Bessemer that can well be spared for first quarter. Bessemer has remained at $17.50, valley, as a minimum, but higher prices have been done on some lots, and a sale of 2,000 tons was made at $17.75. Prices are firm as follows: F. o. b. valley furnace: Bessemer, $17.50 to $17.75;

basic, $17.25 to $17.50; No. 2 foundry, $17.25 to $17.50; forge, $16.25 to $16.50. Delivered Pittsburg: Bessemer, $18.35 to $18.60; basic, $18.10 to $18.35; No. 2 foundry, $18.10 to $18.35; forge, $17.10 to $17.35. F. o. b. Birmingham: No. 2 foundry, $14.00 to $14.50; gray forge, $13.00 to $13.50. Delivered Philadelphia: No. 2 X foundry, $18.25 to $18.75; standard gray forge, $16.25 to $16.50. Delivered Chicago: northern No. 2 foundry, $19.25 to $19.50; malleable Bessemer, $19.50 to $20.00; Lake Superior charcoal, $20.00 to $20.50. Freight: Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65; to Philadelphia by water, $3.50; by all-rail, $4.00; valleys to Pittsburg, 85 cents; to Chicago, $2.30.

Ferro-Manganese. — Prompt ferro has been at famine prices, and sales of single carloads for guaranteed spot shipment have easily been made at $125 and higher prices, it is claimed in one case up to $175. There was some hope recently that the trouble in Russia would be over shortly and a regular supply of metal be available by the beginning of May, but this is now very doubtful. Some manganese ore is being mined in the Caucasus, but far from the normal tonnage, and even with a full supply it would take several months before an adequate supply of metal could be put in the hands of consumers. Some contracts have been made, without any strike clause, for deliveries beginning May 1 at around $85, but it is very doubtful if such contracts could now be made.

Steel. — The Ohio mill, Youngstown, of the Carnegie Steel Company, was put on to sheet bars and billets on January 1, after having been on rails, with the usual small tonnage of billets, since July 1. By the middle of December the Carnegie Steel Company had gotten about 100,000 tons behind on its billet and sheet-bar obligations, with other subsidiaries of the United States Steel Corporation and with outsiders. With the help from Youngstown, and help elsewhere from the easing up of pressure for rail deliveries consequent upon the advent of winter, the company will be able to catch up in a couple of months or so. The market is no easier on Bessemer billets, which are still $26.00, Pittsburg, but open-hearth billets can now be had at about the same price. Sheet bars are about $27.00, Pittsburg; forging billets, 0.35 to 0.45 per cent carbon, are $29.00 and wire rods $32.50 to $33.00.

Rails. — Booking of rail orders was quite heavy during December, and the rail mills of the country enter the new year with more than 2,000,000 tons on their books, equal to two thirds the highest production yet recorded in a calendar year. The Illinois Steel Company cleaned up its 1905 obligations before the end of December and immediately started on its 1906 orders, despite which fact it has been considered necessary to transfer 100,000 tons of orders from Chicago to Pittsburg. The price of standard rails remains at $28.00, f. o. b. mill.

Shapes. — There has been fairly heavy booking, and specifications have been very heavy on old contracts. The Carnegie Steel Company is not promising deliveries on ordinary new business before the third quarter. Mill prices are unchanged, based upon 1.70 cents for beams and channels, 15-inch and under, angles 2 x 3 to 6 x 6 inclusive and zees.

Plates. — The mills have again decided not to advance prices, and it is settled that there will be no change until conditions are very materially different. The regular mill price is based upon 1.60 cents, Pittsburg, for tank quality, quarter-inch and heavier, $6\frac{1}{4}$ to 100 inches wide inclusive.

Merchant Bars. — The regular mill price of steel bars remains at 1.50 cents, Pittsburg, but one or two producers are independently quoting 1.60 cents. Iron bars have advanced more or less in all markets. The Republic Iron and Steel Company since the middle of December has been quoting a minimum of 2 cents, f. o. b. Youngstown or Chicago, and has obtained this price on a few contracts. Some bars have been obtainable at 1.90 cents, delivered Pittsburg, and at 1.85 to 1.90 cents, delivered Chicago. Delivered Philadelphia from $1.83\frac{1}{2}$ to $1.93\frac{1}{2}$ cents is being done on refined bars.

Sheets. — Specifications have been very heavy on contracts for sheets made before the advance of November 20, and there has been some new buying besides, so that altogether the sheet market is quite strong. The new prices are based on 2.30 cents for black and 3.35 cents for galvanized, No. 28 gauge, f. o. b. Pittsburg. Tin plates remain at $3.40, less 5 cents rebate, for 100-pound cokes.

Scrap. — It appears that the expectation was too universal that scrap would be scarce and dear this winter. The ample provision made against a scarcity, together with the extremely

good weather which prevailed during December, has caused a decided weakness and the market has declined openly from 25 to 75 cents in the different grades, being relatively weak at the lower prices.   Some odd lots have been sold at much below the regular quotations of dealers to consumers, which are now about as follows, delivered Pittsburg: heavy melting scrap, $17.50; cast borings, $10.75; No. 1 wrought scrap, $19.50.

Connellsville Coke. — Owing partly to the good weather and partly to the very full operation of all producers, the coke market is easier than it was a month ago.   Strictly Connellsville furnace coke for prompt shipment can be had at $2.75 and 72-hour foundry at $3.50.

RECENT PUBLICATIONS

Elementary Practical Metallurgy, Iron and Steel, by Percy Longmuir. 269 5 × 7½-in. pages; illustrated. Longmans, Green & Co. New York and Bombay. 1905. Price, $2.50. — The author informs us in his preface that the purpose of his book is to awaken interest, and that it is designed to serve as an introduction to the metallurgy of iron and steel, and as such has been written from a practical standpoint. On the whole, the book consists in a number of rather disconnected and crude digressions on the methods employed in the metallurgy of iron and steel and on the properties of the resulting products. There is throughout the author's treatment of his subject a lack of method and of balance which must greatly reduce the value of his book for any class of readers. To justify these criticisms it will suffice to mention the chapter on Bessemer steel in which this subject is dismissed in 10 short pages, the only illustration being that of a Tropenas converter, while 19 pages are devoted to the crucible steel process, and 23 to the open-hearth steel process. There is much merit in brevity, but it may be carried too far, and the author's description of the Bessemer process and of some other operations will hardly satisfy the layest of the laymen. That the author has in mind English practice exclusively is evidenced by his stating that the average content of 2½ per cent silicon gives the best results in the Bessemer process; that graphite crucibles are used to a limited extent in steel melting practice; that blast furnaces are usually tapped twice in twenty-four hours, and by many other statements of a similar nature. There are many statements in the book to which exception could be taken. A few instances only need be mentioned. In his introduction the physical testing of metals is quite unexpectedly dealt with, and we are told that the ductility is measured by the reduction in area, and also that extensibility is measured by the stretch of a test-piece; thus giving to these two words different meanings, quite contrary to the general custom, by

which the elongation rather than the reduction is taken as indicating the ductility, while extensibility merely means the power to elongate, being, therefore, quite synonymous to ductility. In his classifications of the fuels the author distinguishes sharply between coal and anthracite, using the former term as synonymous of bituminous coal and leading the reader naturally to infer that the latter is not coal, although a little later we are told that anthracite is the oldest coal of the series. The artificial gaseous fuels are divided into water gas, Siemens gas, Wilson gas and Mond gas, the word producer gas not being used in the classification. We are then told that the most important of these gases are those of Siemens, Wilson and the water gas producer. The Wilson gas producer is briefly described, but there is no further reference to the so-called " Siemens gas " nor to Mond gas. The treatment of coal in a gas producer is compared to distillation; that this is entirely erroneous need not be insisted upon, seeing that the essential feature of distillation is absence of combustion, unless it be the incidental combustion of some of the substance to provide the heat required for the distillation of the balance of that substance. Distillation implies the separation of volatile from non-volatile matters and never the burning of the latter such as takes place in the gas producer. Describing the use of blast-furnace slags it is stated that phosphoric slags are used in a powdered state as fertilizers by the agriculturists, the author having evidently in mind the slag from the basic-Bessemer converter. The carbon present in pig iron is said to vary between $1\frac{1}{2}$ and $4\frac{1}{2}$ per cent. If by pig iron the author means, as he probably does, the product of the blast furnace, it would be interesting to know by what management the carbon can be reduced to $1\frac{1}{2}$ per cent or even below 2 per cent.

With regard to the metallography of iron and steel, the author espouses *in toto* the views of his former teacher, Professor Arnold.

To sum up our criticisms, it seems to us that the book shows many indications of a lack of that careful preparation leading to mastery of the subject which should always precede the writing of a book.

Gas, Gasoline and Oil Engines, by Gardner D. Hiscox. 442 $5\frac{1}{2} \times$ 9-in. pages; 351 illustrations. The Norman W.

Henley Publishing Company. New York. 1906. Price, $2.50.
— This is the fifteenth edition of a well-known book. It treats
of the theory of gas, gasoline and oil engines as designed and
manufactured in the United States. Explosive motors for
stationary, marine and vehicle power are fully treated, together
with illustrations of their parts and tabulated sizes; also their
care and running are included. Electric ignition by induction
coil and jump sparks are fully explained and illustrated, includ-
ing valuable information on the testing for economy and power
and the erection of power plants. It also contains special
information on producer and suction gases. The rules and regu-
lations of the Board of Fire Underwriters in regard to the instal-
lation and management of gasoline motors is given in full, as well
as suggestion for the safe installation of explosive motor power.
A list of the leading gas and oil engine manufacturers in the
United States and Canada, with their addresses, is included, as
well as a list of United States patents issued on gas, gasoline
and oil engines and their adjuncts from 1875 to date. The
practical character of the book commends it to those concerned
with the installation or running of internal combustion engines
and gas producers.

Cours de Chimie Physique, by Victor Henri. Complete in
two parts. First part, 336 6½-in. × 10-in. pages; illustrated.
Paper covers. Librarie Scientifique. A. Hermann. Paris. 1905.
Price of both parts, 15 francs. — The importance of physical
chemistry is every day becoming more evident, and its study
is constantly attracting new recruits. In the book before us
and which represents in substance a course of lectures deliv-
ered at the Faculty of Sciences of Paris, the author presents
clearly and methodically the fundamental principles of the
science. His purpose was to write an elementary course of
physical chemistry such as would be readily comprehensible
to readers possessing only an elementary knowledge of chem-
istry and physics, but, while he has done this in a most satis-
factory manner, his book will also prove instructive and
suggestive reading for advanced students.

Traité de Physique, by O. D. Chwolson. Translated from
the Russian and German editions by Edward Davaux. Com-

plete in four volumes. Vol. I, 407 6½ × 10-in. pages; 219 illustrations. Paper covers. Librarie Scientifique. A. Hermann. Paris. 1906. Price, 16 francs. — The present edition has been revised and enlarged by the author, who is professor at the Imperial University of St. Petersburg, and it contains also some notes on theoretical physics by E. Cosserat and F. Cosserat. The first volume deals chiefly with mechanics and the methods and instruments of measurement. Professor Chwolson's treatise was first published in Russian, in 1897, and its importance was soon realized by physicists in all countries. A German translation was begun in 1902 and three volumes have now been published. The present French translation of so important a book cannot fail to be warmly welcome by physicists and scientists possessing the necessary knowledge of the language.

Der Eisenbau (A Handbook for Structural Steel Design), by Luigi Vianello. 691 5 × 8-in. pages; illustrated. P. Oldenbourg. Munich and Berlin. 1905. Price, $7.00. — In this valuable book the author has combined a theoretical study of framed structures, together with numerous tables for ready references such as are generally found only in pocketbook editions, and in this dual character lies the chief value of the volume we have before us. It should appeal strongly to designers of steel structures. In an appendix of some eighty pages, by Gustav Schimpff, tables are given of I's and channels of German manufacture. The book is well printed and illustrated and the paper excellent.

A Textbook of Chemical Arithmetic, by Horace L. Wells, professor of analytical chemistry and metallurgy in the Sheffield Scientific School of Yale University. 169 4½ × 7½-in. pages. John Wiley & Sons. New York. 1905. Price, $1.25. — The following extracts from the author's preface will clearly indicate the aim and scope of this book: " This book is designed especially for the use of students of quantitative analysis, many of whom, even after having taken extensive courses in higher mathematics, show little ability to solve simple chemical problems. Certain portions of the work are suitable also for the use of those who are studying elementary chemistry. The subject is presented, as far as possible, in the simplest arith-

metical manner, use being made of reasoning rather than rules and mathematical formulas. It must be admitted that arithmetic is very difficult for those who depend chiefly upon memory, but it has the advantage of being a means of developing the reasoning power, which is undoubtedly a higher mental faculty than memory, and is also a valuable attainment as a preparation for a career in chemistry. The first part of the book, dealing with approximate numbers, has been introduced on account of the poor judgment displayed by many students in carrying out decimals in the results of their work. The very useful methods of abbreviated multiplication and division are introduced here for the benefit of those who may not be familiar with them."

This is certainly a useful and in some respects unique book, which should appeal strongly to all students of analytical chemistry.

The Mechanical World Pocket Diary and Year Book for 1906. 391 4 × 6-in. pages; illustrated. Emmott & Co. Manchester. 1905. Price, sixpence. — The nineteenth edition of this little book contains the usual collection of useful engineering notes, rules, tables and data. To the present edition, however, considerable new matter has been added pertaining to branches of engineering practice of growing importance, such as steam turbines, speeds and feeds for high-speed steel tools, gas and oil engines, etc.

Theory of Structures and Strength of Materials, by Henry T. Bovey, professor of civil engineering and applied mechanics in McGill University. 981 6 × 9-in. pages; 943 illustrations. John Wiley & Sons. New York. 1905. Price, $7.50. — This is the fourth edition of Professor Bovey's well-known and important treatise. The present edition has been rewritten and enlarged, the number of pages having been increased from 852 to 981, and the number of illustrations from 515 to 943. Numerous examples, drawn for the most part from actual practice, have been added to the several chapters, and a large number have been worked out in detail throughout the text so as to illustrate the principles of strength, construction and design. Chapter X on Bridges presents the subject in a somewhat new

manner, giving the principles now generally adopted in engineering design. The tables of strengths, elasticities, weights, etc., have been carefully revised, increased in number and brought up to date.

This new edition of Professor Bovey's work cannot fail to be warmly welcomed by the engineering profession. The printing, illustrations, paper and binding of the book is fully equal to the usual high standard of the publishers.

Handbook of Metallurgy, by Dr. Carl Schnabel. Translated by Henry Louis. Second edition. Vol. I: Copper, Lead, Silver, Gold. 1,123 6 × 9-in. pages; 715 illustrations. Macmillan & Co. London. 1905. Price, $6.50. — This is the translation of the second German edition of this important book which appeared in 1901. The second volume was published in German in 1904, and the publishers promise to have the translation ready early in 1906. In this second edition of the first volume the subject has been extensively revised and enlarged. In the first edition the index for both volumes was placed at the end of the second volume, but in the present edition a separate index has been carefully prepared, covering some twenty pages, which greatly adds to the value of the book for ready reference. The present volume deals with copper, lead, silver and gold. This metallurgical treatise is undoubtedly a work of great value, to which the student as well as the practitioner may refer for reliable information in almost any field of the metallurgical art excepting iron and steel, and it is in many respects unrivaled by any other work in metallurgy.

A natural criticism is that the author devotes too much space and minute description to processes now obsolete, but his excuse for this is given in his preface, where he states that, "since a knowledge of the development of metallurgy from the earliest periods is of especial value to the metallurgist, and more particularly in stimulating his inventive genius, particular attention has been devoted to the older metallurgical methods and appliances."

Practical Methods of Electro-Chemistry, by F. Mallwo Perkin, Ph.D. 332 5½ × 8½-in. pages; illustrated. Longmans, Green & Co. London, New York and Bombay. 1905. — The author,

who is head of the chemistry department at the Borough Poly-
technic Institute in London, states in his preface that he has
written this book in the hope that interest in electro-chemistry
might be stimulated. With a few exceptions, all the experi-
mental work has been carried out in his own laboratories. The
treatment is divided into three parts, the first one being devoted
to general consideration, the second to electro-chemical analysis
and the third to preparations by electrolytic means.

BOOKS RECEIVED

The following books have been received and will be reviewed in an
early issue of the *Iron and Steel Magazine.*

Bossism and Monopoly, by Thomas Carl Spelling. 358 5 × 7½-in.
pages. D. Appleton & Co. New York. 1906.

Electrolytic Dissociation Theory, by Henry P. Talbot and A. A.
Blanchard. 84 6 × 9-in. pages; illustrated. The Macmillan Company.
New York. Price, $1.25.

Select Methods of Quantitative Analysis, by Byron W. Cheever and
Frank Clemes Smith. Fourth edition, revised and enlarged. Parts
I and II, 273 5½ × 9-in. pages. George Wahr. Ann Arbor, Mich. 1905.
Price, $2.00.

The Production of Aluminum and Its Industrial Use, by Leonard
Waldo. 266 5 × 7½-in. pages; illustrated. John Wiley & Sons. New
York. 1905. Price, $2.50.

Transactions of the American Electrochemical Society. Vol. VII.
345 5½ × 9-in. pages; illustrated. Published by the Society. Phila-
delphia, Pa. 1905.

Engineering Chemistry, by Thomas B. Stillman. Third edition.
597 6 × 9-in. pages; illustrated. Chemical Publishing Company.
Easton, Pa. 1905. Price, $4.50.

Second Year Chemistry, by Edward Hart. 165 5 × 6½-in. pages; illus-
trated. Chemical Publishing Company. Easton, Pa. 1905. Price, $1.25.

Technological and Scientific Dictionary, edited by C. F. Goodchild
and C. F. Tweney. Complete in 15 parts. Part XI, 64 7 × 10-in.
pages; illustrated. George Newnes, Ltd. London. Price, each part, 1s.

Pig-Iron Almanac, 1905–1906. 108 3 × 5-in. pages. Rogers, Brown
& Co. Cincinnati.

Quantitative Metallurgical Analysis, by Charles Frederick Sidener.
58 5½ × 8-in. pages; illustrated. H. W. Wilson Company. Minneapo-
lis, Minn. 1904. Price, $1.00.

Minerals in Rock Sections, by Lea McIlvaine Luguer. Revised
edition. 141 6 × 9-in pages; illustrated. D. Van Nostrand Company.
1905. Price, $1.50.

Practical Pattern-Making, by F. W. Barrows. 5 × 7-in. pages; 141
illustrations. The Norman W. Henley Publishing Company. New
York. 1906. Price, $2.00.

Le Vanadium. by P. Nicolardot. 177 4 × 7½-in. pages; paper
covers. Gauthier Villars. Paris. Price, $0.75.

The Science Year Book for 1906. 360 5½ × 9-in. pages; illustrated.
Edited by Major B. F. S. Baden Powell. King, Sell & Olding, Ltd.
London. Price, 5s.

Les Fours Électriques et leurs Applications Industrielles, by Jean
Escard. 535 6½ × 10-in. pages; illustrated. Paper covers. Vve. Ch.
Dunod. Paris. 1905. Price, 18 francs.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

804,402. MACHINE FOR MANUFACTURING BRIQUETTES. — Gottfried Hoepfner, Bleckendorf, Germany, assignor to Willy Von Lewinski, Breslau, Prussia, Germany.

804,692. PREPARING IRON OXIDE FOR USE IN BLAST FURNACES. — Utley Wedge, Ardmore, Pa.

804,693. PREPARING IRON OXIDE FOR USE IN BLAST FURNACES. — Utley Wedge, Ardmore, Pa. .

804,814. GAS PRODUCER. — Edward Krenz, St. Louis, Mo.

805,106. PLANT FOR MAKING BRIQUETTES. — John Treadwell, San Francisco, Cal.

805,235. PRODUCER GAS FURNACE. — Paul Schmidt and Adolphe Desgraz, Hanover, Germany.

805,448. MAGNETIC SEPARATOR FOR ORES. — Henry F. Campbell, Melrose, Mass.; Jeanette L. Campbell, executrix of said Henry F. Campbell, deceased.

805,563. MANUFACTURE OF STEEL. — Horace W. Lash, Cleveland, Ohio, assignor to the Garrett-Cromwell Engineering Company, Cleveland, Ohio, a corporation of Ohio.

805,564. MANUFACTURE OF STEEL. — Horace W. Lash, Cleveland, Ohio.

805,728 and 805,729. PROCESS OF PERFECTING CASTING STEEL INGOTS. — Robert W. Hunt, Chicago, Ill.

805,737. APPARATUS FOR CHARGING FURNACES. — Edward W. Lindquist, Chicago, Ill., assignor to Ralph Baggaley, Pittsburg, Pa.

805,836. METHOD OF PRODUCING IRON. — Ralph Baggaley, Pittsburg, Pa.

805,854. MAGNETIC ORE SEPARATOR. —Eric Hedburg, Joplin, Mo., assignor, by mesne assignments, to American Reduction Company, Chicago, Ill., a corporation of Arizona.

806,179. MOLDING MACHINE. — William J. Patchell, St. Louis, Mo.

806,208. APPARATUS FOR STRIPPING MOLDS FROM INGOTS. — Clarence L. Taylor, Alliance, Ohio, assignor to the Morgan Engineering Company, Alliance, Ohio.

806,845. MANUFACTURE OF BRIQUETTE FUEL FROM COAL-MINE WASTE OR DUST-COAL. — Thomas Rouse and Hermann Cohn, London, England.

LÉON GUILLET

THE INDUSTRIAL FUTURE OF SPECIAL STEELS *

By LÉON GUILLET

THE recent industry of special steels was for a long time satisfied with creating at random many types of special steels, varying greatly and which a rapid selection has reduced to a few well defined compositions.

At the present time, when the modern theories have made possible the study of these complex alloys, it seems interesting to review the industrial future of these various special steels.

They may be classified in a general way as follows:

1. Ternary steels, composed of carbon, iron and a third constituent introduced purposely.

2. Quaternary † steels, composed of iron, carbon and two other constituents.

At the present time the arts do not call for more complexed steels. It is, of course, understood that a steel containing only some traces of elements always found in iron products, such as manganese, silicon, sulphur, phosphorus, etc., will not be considered as a special steel.

The most important ternary steels actually utilized in various industries are the following:

Nickel steels, which are the most important.

Chromium steel, utilized in a few special instances.

Hadfield manganese steel.

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* Received January 4, 1906.

† Quaternary (French, *quaternaire*), made up of four constituents. The word is not in the Century Dictionary, but it is used here for convenience of speech. — ED.

Tungsten steels, employed as tool steels or for permanent magnets.

Molybdenum steels, as yet but little used, although efforts are being made on good ground to employ them instead of tungsten steels.

Silicon steels, the use of which is greatly increasing, chiefly because, as it will be shown, of their low price.

Much has been said about utilizing aluminum steels, because of their feeble hysteresis, for electric constructions, but we do not believe that these steels are at present manufactured in large quantities.

The vanadium steels have not yet a great importance and we will study their future a little later.

The most important quarternary steels used at present are:
Nickel-chromium steels, widely used.

Chromium-tungsten steels, which constitute the famous high-speed steels, one of the most important and remarkable discoveries of the modern metallurgy of iron.

Finally, two kinds of steels recently prepared, but which will undoubtedly soon assume much importance, namely, the nickel-vanadium steels and the chromium-vanadium steels.

Classification. — The microscopical examination of ternary and quaternary steels leads to an extremely simple classification of these special steels.

We have described in a series of articles published in the "Revue de Métallurgie" and the "Bulletin de la Société d'Encouragement," the researches which we have made concerning the properties of these ternary special steels, while the exhaustive investigations which we have just completed, dealing with quaternary steels, will be presented shortly to the Iron and Steel Institute as a Carnegie Research Scholarship report. These recent investigations include the study of the following steels: nickel-manganese steels, nickel-chromium steels, nickel-tungsten steels, nickel-molybdenum steels, nickel-vanadium steels, nickel-silicon steels, nickel-aluminum steels, manganese-silicon steels and chromium-tungsten steels. We also are completing an investigation of chrome-vanadium steels. From these studies we are able to affirm that the only types of structures assumed by these ternary and quaternary steels after reheating to 900° C. and cooling slowly may be reduced to 5

types: (1) pearlitic steel, (2) martensitic steels, (3) gamma iron steels, (4) carbide steels (although containing less than 0.85 per cent carbon) and (5) graphitic steels.

From the study of the mechanical properties of these special steels we conclude that among these structures the only one of value for mechanical constructions are the pearlitic steels and the gamma iron steels, and that even the latter present some objections which will be indicated later.

Martensitic Steels. — Martensitic steels or troostite steels are always those containing nickel, manganese or chromium when they are ternary; if they are quaternary they may contain important amounts of another element, such as tungsten, silicon, vanadium, etc. All the steels assuming a martensitic structure after reheating show a very high tenacity and elastic limit, a very feeble elongation and reduction of area and a low resistance to shock. They are very hard and extremely difficult to machine as well as to forge. Because of these difficulties their application has been abandoned. Nickel steels, for instance, containing a medium amount of nickel, are no longer manufactured. We have, however, shown on many occasions that the passage of a pearlitic structure to a martensitic structure as well as of a martensitic structure to a gamma iron structure is not sudden; there exists a transition zone which it seems to us is interesting from an industrial point of view; unfortunately these zones are relatively narrow and it is undoubtedly true that a feeble variation in the chemical composition may lead to the passage of the steel into one of the well defined zones. We conclude that the martensitic steels are not susceptible of industrial application.

Gamma Iron Steels. — Gamma iron steels may contain either nickel, manganese or, of course, both nickel and manganese. It is even possible to introduce a certain amount of chromium or tungsten or vanadium in a nickel or manganese steel presenting the gamma iron structure without changing that structure. The mechanical characteristics of gamma iron steels are as follows: Medium tenacity, low elastic limit, very high elongation and reduction of area and remarkable resistance to shock. The defects of gamma iron steel reside in two points which are too often overlooked: (1) A very low elastic limit and (2) considerable difficulty in machining, although, of course, much less than

the difficulty presented by martensitic steels.   They possess the great advantages of a very high resistance to shock and a very feeble wear, which is almost *nil* in the case of friction upon hard, medium soft, soft or extra soft bronze.   But there is another point which should not be forgotten and which has given rise to serious apprehensions in some manufactures and especially in the manufacture of automobile valves: gamma iron steels which are close to the martensitic steels are easily converted through cold working, cooling, reheating, quenching, etc., into martensite, which results in brittleness and which takes place with an increase in volume.   It is in this way that the use of the famous ferro-nickel led to disappointments.   It should also be borne in mind that gamma iron steels are always expensive, especially those containing nickel.   It might be interesting to prepare some gamma iron steels containing both nickel and manganese and which might be less expensive than those containing simply nickel.   Those which contain manganese only are very difficult to machine.   To sum up, and leaving aside a few special applications in the case of some ordnance pieces, gamma iron steels do not appear to have before them that very promising future which some metallurgists, including the writer, had at first conceived; their price is too high, their working too difficult and their elastic limit too low. It remains true, however, that in some cases, especially in the manufacture of valves or when resistance to corrosion is needed without fear of a low elastic limit, they are destined to render real services.   It may be added, moreover, that their elastic limit may be slightly raised through an addition of chromium.   Finally, among the gamma iron steels, two are found which are susceptible of extremely remarkable applications.   We have in mind *invar* steel of Guillaume, which contains 36 per cent nickel and which has only a very feeble dilatation, between zero and 350 degrees, and is utilized in geodesy, metrology and clock making, and a steel with 46 per cent nickel which has the same coefficient or dilatation as glass and may therefore replace platinum for the manufacture of incandescent lamps and which, on that account, is known as *platinite*.

Carbide Steels. — These steels, which, although containing less than 0.85 per cent carbon, contain some carbide, may be either some chromium, tungsten, molybdenum or vanadium steels, if they are ternary.   Such structure is met with in a

great number of quaternary steels, provided they contain one of the above four metals. Among these quaternary steels should be especially mentioned the chromium-tungsten steels or so-called high-speed steels. It should be noted, moreover, that while the steel contains some grains of carbide the background of the structure may be formed either of martensite (as in the case of chromium steels or of the quaternary steels already mentioned, but containing some nickel, manganese or chromium) or of gamma iron (as in the case of chromium steels or of the quaternary steels already mentioned, but containing some nickel or manganese), or of a constituent which recalls sorbite (as in the case of chromium, tungsten or molybdenum steels or of chromium-tungsten steels, etc.), or again of ferrite (as in the case of vanadium steel). In every instance, the constituent which imparts its properties to the steel is that which constitutes the matrix, from which it follows that the steel will have high elastic limit and tenacity when martensite is present, a medium value of those properties when sorbite is present, a low value with ferrite, a medium tenacity and low elastic limit with gamma iron. The carbide imparts either a medium brittleness (as in the case of tungsten and molybdenum steels or of chromium-tungsten steels) or a very slight brittleness (as in the case of chromium or vanadium steels). It should be noted that these carbide steels frequently exhibit a high elongation notwithstanding their great brittleness. Because of their lack of resistance to shock, carbide steels are not adapted to mechanical constructions. Some of them, however, after a certain thermal treatment, acquire a very high mineralogical hardness and on that account are used for certain purposes, as, for instance, in the manufacture of steel balls.

Chromium Steels. — The most likely increased application of these steels seems to be for the manufacture either of ordinary tools (chromium steel for files, etc., tungsten steel) or more especially for high-speed steels.

Graphite Steels. — This structure is found only in normal steels when they contain a relatively high proportion of silicon. They are not susceptible of any useful applications because of their great brittleness.

Pearlitic Steels. — We have purposely reserved for the last of this article the pearlitic steels, because they are the most inter-

esting of these special steels; their mechanical properties depend
essentially upon the special element present, and it may be said
that, generally speaking, the tenacity and the elastic limit in-
crease with the proportion of that element when the amount of
carbon remains constant. These various elements may influ-
ence the properties more or less rapidly. As little as 0.5 per cent
of vanadium has a very great influence upon the properties,
while as much as 30 per cent of cobalt has a very slight influence.
But, although some of these elements, like tin, render these steels
useless because of their great brittleness, or like titanium and
cobalt, hardly affect them, others, like nickel and manganese,
increase the resistance to shock without decreasing the elonga-
tion, or, again, like chromium and tungsten, increase slightly the
brittleness.

Nickel steels, therefore, are of very great interest and it can
readily be seen why they were soon used extensively. In many
cases, however, they do not possess after quenching sufficient
mineralogical hardness, hence the well known addition of chro-
mium. For many applications it is necessary to have a steel
which after forging can easily be machined and which after
hardening and tempering possesses a high elastic limit without
too great a brittleness. This can only be obtained with difficulty
in the case of pearlitic nickel steels, even with nickel-chromium
steels. On the contrary, nickel steels containing vanadium are in
this respect very satisfactory.

Chromium-vanadium steels should also be noted; their
properties, which are not yet well known, seem to be as follows:
They have a high mineralogical hardness, a high elastic limit and
medium high resistance to shock. These steels, however, being
quite costly, efforts have been made to replace them by pearlitic
silicon steels, which have been for a long time employed in the
manufacture of spring. Their price, which exceeds very little
that of ordinary steels, gives them a wide application, but they
are somewhat difficult to treat. Hardening, and especially
tempering, must be conducted at well defined temperatures.
After a satisfactory thermal treatment they acquire a high
elastic limit without too great a brittleness, at least in the
direction of the rolling, for it is well known that one of the
characteristics of silicon steels resides in their brittleness in a
direction at right angles to the direction of rolling. In spite

of this disadvantage, silicon steel has given excellent results, notably in the manufacture of gearings, and even of some automobile shafts. It might be remarked that it is somewhat hard to the tool, and we are inclined to think that in some cases the use of some nickel steels may more than compensate the difference in price, because of the greater ease with which they can be machined.

Conclusions. — From what has been briefly stated above, and from the point of view of mechanical constructions, we may arrive at the following conclusions:

1. Pearlitic steels are those which present the greater future. It is undoubtedly in that direction that further researches should be conducted. Efforts should be made to discover some steels which, while being easily machined, possess valuable mechanical properties, after a simple thermal treatment, and in this direction vanadium introduced into certain steels appears to give extremely interesting results.

2. Gamma iron steels, although interesting in some particular cases, are too costly and have too low an elastic limit to justify a wide use.

3. Carbide steels are only of interest in the case of very special products, such as steel balls, etc.

4. Martensitic steels are not susceptible of any useful application.

5. Graphite steels cannot be utilized.

Summing up, the field of research into the properties of special steels, which a few years ago seemed so wide and unexplored, is becoming every day narrower, thanks to the modern technical methods, unless experiments be conducted with new elements, at present of interest only in the laboratory, such as borum, uranium, etc.

COOLING CURVES OF METALLIC SOLUTIONS *

By THOMAS T. READ

Department of Mineralogy, Columbia University, New York City

THE study of cooling curves is one of the most valuable and convenient methods that is employed in the investigations of metallography. Although of comparatively recent introduction it has already become widespread, not alone in university laboratories but in the works as well. Metallographists have been so busily engaged in applying the study of cooling curves to the many problems of metallography that few have stopped to discuss the phenomena of cooling curves, and it is not surprising therefore that the causes of the points of inflection which give cooling curves their value are not known to all.
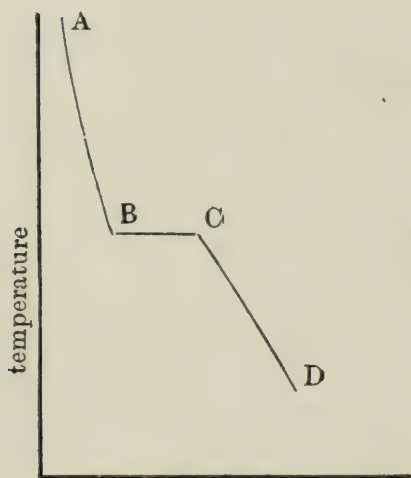
On cooling a molten mass of a pure metal, tin, for example, recording its rate of cooling and plotting the curve theoretically, a curve like Fig. 1 should be obtained.

FIG. 1.

AB represents the cooling curve of the molten metal, B is the point at which solidification begins, or the freezing point of the metal. BC represents the freezing out of the metal. The temperature remains at B until all the metal has frozen because the freezing process liberates the latent heat of fusion, which keeps the temperature constant at B in spite of the fact that heat is being abstracted from the freezing mass just as rapidly as before it began to freeze. The temperature cannot fall below B until the mass is all frozen because any attempt to do so would so accelerate the freezing and consequently the liberation of latent heat as to raise the temperature to B again. On the other hand, it cannot rise above B, for then freezing would at once cease and with it the liberation of latent heat, and the temperature would at once drop back to B. Freezing keeps

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pace with the abstraction of heat, the temperature remaining
constant until it is completed.

As a matter of fact the actual curve obtained from cooling
such a mass of tin is as shown in Fig. 2.

Here we see that the molten tin cooled to E, somewhat
below the freezing temperature of tin. The temperature then
quickly rose to B and remained constant until freezing was com-
pleted at C. AB, as before, represents the cooling of molten tin
and B'C the freezing out of solid tin. The part of the curve BEB'
still requires explanation. This phenomenon is known as sur-
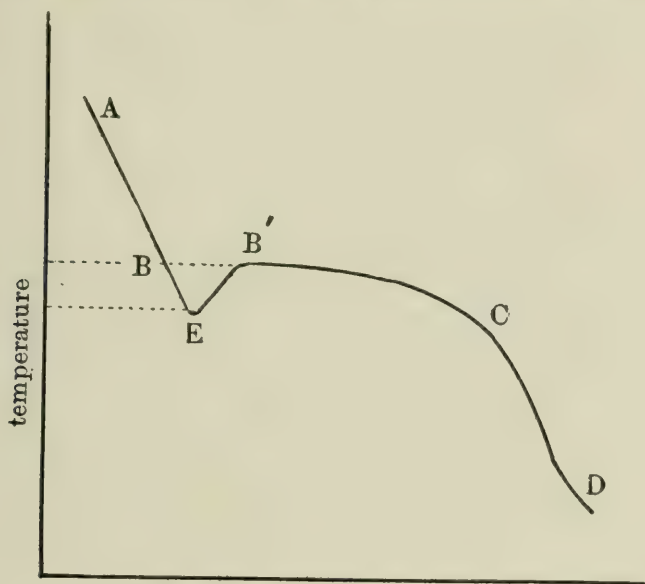
FIG. 2.

fusion and seems to be entirely analogous to undercooling or
supersaturation in liquid solutions. Küster * has suggested an
explanation for the latter. He states that the solubility depends
on the state of division of the dissolved body and suggests that
there may exist particles which he terms " primitive crystals,"
that are so small as to be invisible and that the solution may
not be saturated with respect to these when it is saturated with
respect to particles of appreciable size. The limit between these
is the range of supersaturation or surfusion. On cooling down
a solution to the limit of solubility of the primitive crystals these
separate out, and if particles of appreciable size are introduced
will grow on them. On cooling to the lower limit the normal

* Zs. Inor. Ch., 33 (3), 363–369 (1903).

crystals begin to separate out. Such an explanation does not seem adequate, however, for if the primitive crystals are freezing out the temperature should remain constant at their freezing point. Miers,* following the work of Jaffe,† has pointed out that by cooling a solution of a salt, on reaching the saturation point the salt is at first only able to crystallize out if centers of crystallization are available, and requires to be cooled some distance below this point before it can originate centers of crystallization spontaneously, the range between being known as the labile state. Applying this to our tin we see that on reaching B the solution was not able to originate centers of crystallization and required to be cooled to E before it could p r o d u c e them. Once originated, freezing out was r a p i d and liberated sufficient heat to raise the temperature to B′, where it remained until freezing was complete at C. How important surfusion is in the study of cooling curves will be seen a moment later. The curve CD in each figure will at once be recognized as the cooling curve of solid tin, the gradual transition from BC into CD being due to imperfect conduction.
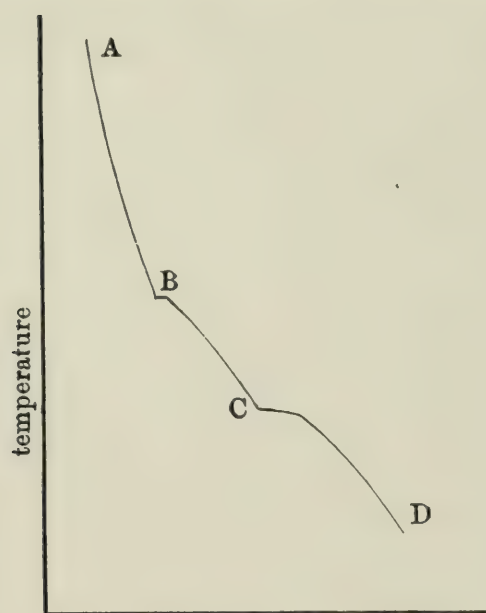
FIG. 3.

Suppose, now, we cool a molten mass of tin containing 10 per cent zinc in solution. The curve will be as in Fig. 3.

As before, the curve AB represents the cooling of the solution. At B something begins to freeze out. This is zinc. The zinc does not all freeze out, however, for zinc and tin together are more fusible than pure zinc. At this temperature only a certain amount of zinc can be held in molten solution by the tin; the excess zinc freezes out. On cooling a degree lower, still less zinc can be held and the excess zinc freezes out as before, the solution gradually growing poorer in zinc until at C (8 per cent zinc) the most fusible composition is reached. It is not obvious

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* " Nature," 72, 405 (1905).
† Zs. phys. Chem., 43, 565–594 (1903).

at first why we should have such a marked change in the curve at B, for the solution must become saturated with zinc a molecule at a time, the evolution of heat should keep pace with the saturation and only a change of direction in the curve should be produced. Surfusion is again the cause; when the solution first becomes saturated with zinc it is not immediately able to originate centers of crystallization and not until it has cooled a slight distance below can these be set up. On reaching this point the accumulated zinc, if we may so term it, all freezes out together, and the sudden liberation of heat produces a marked jog in the curve. This has its advantage, for the jog is easy to detect, while a simple change in direction is difficult to perceive, but has also its disadvantage in that the point marked is a more or less indefinite distance below the true point at which freezing should begin. In most cases, however, this is not a serious error.

The temperature remains constant at C until all the eutectic has frozen. This results from the fact of its being the most fusible alloy of the two metals and the reason is the same as that given for the constancy of temperature during the freezing out in the case of pure tin.

A third cause of points of inflection in a cooling curve is the separation of a compound. This in no way differs from the freezing out of an excess metal and the same discussion applies. Molecular rearrangements which take place in the solid are, then, the only causes of points of inflection in cooling curves which remain to be discussed. These are not in all cases clearly understood, but it is clear that such changes will cause either an evolution or an absorption of heat, and, therefore, a change in direction at least of the curve. Rearrangements in the solid, separation of compounds, freezing of excess metal and of eutectic are all marked by characteristic inflections in the cooling curves of metallic solutions, the surfusion in the case of the excess metal distinctly indicating a point that would otherwise be difficult to detect.

IRON-NICKEL-MANGANESE-CARBON ALLOYS *

THE seventh report of the Alloys Research Committee on the properties of a series of iron-nickel-manganese-carbon alloys by Dr. H. C. H. Carpenter, Mr. R. A. Hadfield and Mr. Percy Longmuir, which formed the subject of discussion at the Institute of Mechanical Engineers on Friday last, occupies 103 pages of text, and is illustrated by 71 figures. It is admirable both in substance and form, but would take far too much space to reproduce in full. We therefore offer an abstract of such parts as lend themselves to that treatment, and refer the reader who desires greater detail to the report itself. The actual words of the report are used almost entirely in this abstract.

(1) The Prussian Society for the Encouragement of Industry,† as far back as 1892, inaugurated a series of investigations on nickel-iron alloys. In the course of a decade six reports were issued, of which practically only the last overlaps, and then only in a few places, the ground covered in the present research. These reports deal only with the mechanical and working properties of the alloys. (2) In 1903, M. Guillet ‡ published the results of experiments, in which the mechanical and working properties were correlated to the structures, with three series of nickel steels, in each of which the nickel varied from 2 to 30 per cent, and the carbon was .12, .22 and .82 per cent on an average per series. These series, although low in manganese, are in other respects comparable with the authors' series and offer points both of comparison and contrast.

The resources of the National Physical Laboratory have enabled the authors to investigate an unusually wide range of the properties of their alloys. which may be grouped under (a) mechanical, (b) physical — including metallographical, and (c) chemical heads; and with respect more particularly to physical qualities it has been possible to compare and contrast results with those obtained. notably by M. Osmond and M. Guillaume in the same field.

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* " The Engineer," November 24, 1905.
† Berichte des Sonderausschusses für Eisen-Nickel-Legierungen (1892–1902).
‡ " Bulletin de la Société d'Encouragement pour l'Industrie Nationale," May, 1903.

The literature of the so-called " Theory of the Nickel Steels," which is almost exclusively a product of modern French thought, and which at the present time endeavors to account for the properties of these steels on the basis of allotropic modifications both of iron and nickel, hardly comes in the same category as the work described by the authors. Nevertheless, they venture to think that their experimental results, more especially in the physical section of the report, may have interesting theoretical consequences.

The series of nickel-manganese-carbon-iron alloys, A–K, whose properties have formed the subject of investigation of this research, has been prepared with Swedish charcoal iron of special purity. This was melted along with the necessary ingredients, nickel and Swedish white iron. By these means approximately uniform percentages of carbon and manganese were obtained, the nickel varying from nil to 20 per cent as aimed at, as shown by Table I.

TABLE I

Nickel Alloy	Percentages		
	Nickel	Carbon	Manganese
A	Nil	0.47	0.95
B	1.20	0.48	0.79
C	2.15	0.44	0.83
D	4.25	0.40	0.82
E	4.95	0.42	1.03
F	6.42	0.52	0.92
G	7.95	0.43	0.75
H	12.22	0.41	0.85
J	15.98	0.45	0.83
K	19.91	0.41	0.96

Of these the last six sample bars had to undergo heat treatment before they could be machined to form test pieces.

In order to obtain strictly comparative conditions, all the tests have been conducted on " material " that has been heated to 800° C., which safely clears the critical ranges, and this temperature was, therefore, selected as most suitable for normalizing a series of steels of very dissimilar critical ranges.

MECHANICAL TESTS OF FORGED STEELS

The bars employed for bending tests were $\frac{1}{2}$ inch in diameter, by 8 inches in length. About one third of the bar fitted into a

$\frac{9}{16}$-inch hole drilled in a solid anvil, and the free end was turned over by blows from a " striking " hammer. The first four members of the series all bent parallel, and in doing so developed no apparent flaws. The fifth steel marks a pronounced change, and breaks at the comparatively small angle of 30 degrees. Yet the content of nickel in E is only .7 per cent greater than in D, a steel which bent parallel without sign of flaw. There is a difference of .21 per cent in the content of manganese, and a very slight one of .02 per cent in carbon. Such differences, however, can hardly affect the issue, and the change in properties must be

FIG. 1.—*Bending Tests.*
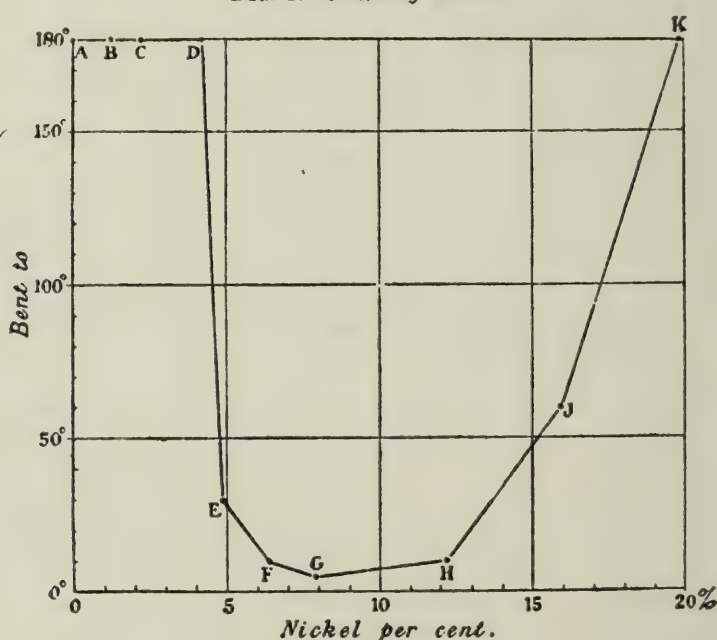
due to nickel. Further increments of nickel decrease the bending angle until a minimum is reached at a content of 7.95 per cent. Still further increments of nickel mark the gradual return of ductility, as shown by angles 10, 60 and 180 degrees for steels containing respectively 12.22, 15.98 and 19.91 per cent of nickel. The last steel, containing nearly 20 per cent nickel, not only bent parallel, but was afterwards closed up, a procedure which developed no visible flaw. These tests are shown diagrammatically by Fig. 1.

The average dimensions of the tensile test-pieces employed were $\frac{3}{8}$ inch in diameter by 2 inches parallel. Maximum stress increases fairly gradually up to D, and at the same time ductility

does not seriously decrease. For some reason not yet apparent the ductility of B is less than that of C. The abrupt change between D and E noted in the bending is further emphasized in the tensile tests, and it will be noted that an increase in nickel of .7 per cent raises the maximum stress some 12.23 tons per square inch, at the same time decreasing the elongation by 18 per cent. Ductility has disappeared entirely in F, which gives the maximum tensile strength of the series. K, 19.91 per cent nickel, is characterized by the lowest yield point, the highest elongation and reduction of area of the series. This steel, remarkable in

FIG. 2.—*Tensile Tests.*

Elongation, Reduction of Area, and Twisting Angle.
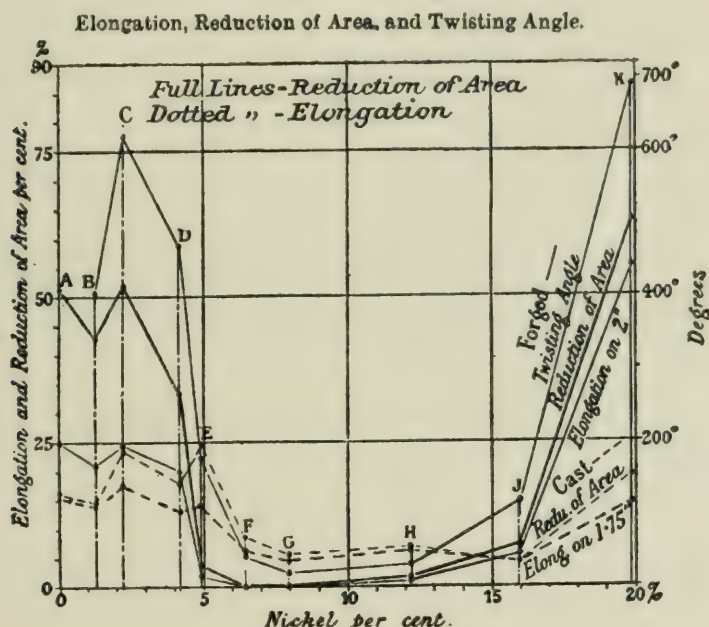
many respects, derives its chief interest here from the fact that an ultimate stress of 43.9 tons per square inch is associated with an elongation of 55 per cent on 2-inch. The foregoing tensile results are plotted on three separate curves. (See Figs. 2, 3 and 4.) The yield points noted in tension are plotted on Fig. 3. The maximum stress curve plotted on Fig. 4 specially emphasizes steel F, and at the same time shows the influence of an ascending content of nickel.

Finally, both tensile and bending tests show that the series of steels may be roughly divided into two groups, one including ductile and the other brittle steels. Up to 4¼ per cent nickel, ductility is fairly high; 4.95 per cent nickel marks an accession

of brittleness, whilst 15.98 per cent nickel denotes the return of ductility. This return is complete at 19.91 per cent nickel.

Compression tests were made on cylinders .35 inch in diameter by .56 inch high, these dimensions being selected in order to attain a maximum load equal to 100 tons per square inch. The compressibility of the series decreases with an increase of nickel until a minimum is reached at G, 7.95 per cent nickel. The compression curve (Fig. 5) has a strong resemblance to preceding curves representing different aspects of ductility. It will, however, be noted that, in the return of the curve, the right-hand branch does not attain its initial height.

Under shock tests only three of the steels fractured, the remaining specimens bending to a greater or less extent. Gen-

FIG. 3.— *Yield Points.*
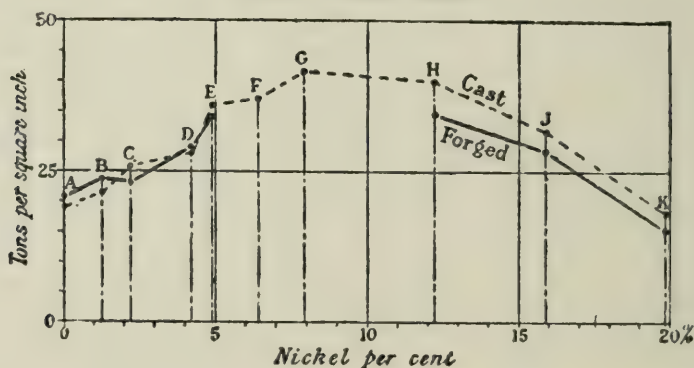
erally speaking, the differences between the first four steels — those that did not break — are not great; they were all bent, and shock developed no visible flaw in any one. When, however, the nickel content is raised from 4.25 to 4.95 per cent, then decisive brittleness under shock is shown; this increment of only .7 per cent results in the steel fracturing with comparative ease. The minimum is found with F, a result which coincides with that of the same steel under tension. The behavior of H is noteworthy, a steel which in the preliminary bending tests fractured on reaching an angle of 10 degrees. Under shock this steel absorbs 436 inch-pounds, and bends to an angle of $7\frac{1}{2}$ degrees without developing any apparent flaw. The expenditure of an equal amount of work in the case of A and K shows the higher ductility of the latter, even when that work is applied as shock.

PROPERTIES OF THE SERIES OF ALLOYS. CONDITION OF MATERIAL. FORGED AND COOLED FROM 800° C. (1472° F.)

Ni Alloy	ANALYSES			Bending Test	TENSILE TESTS			
	Ni	C	Mn		Yield Point	Maximum Stress	Elongation on 2 in.	Reduction of Area
	Per cent	Per cent	Per cent	Bent to	Tons per sq. in.	Tons per sq. in.	Per cent	Per cent
A	—	0.47	0.95	180° U.	21.00	38.19	25.0	51.73
B	1.20	0.48	0.75	180° U.	23.93	40.93	21.0	42.85
C	2.15	0.47	0.86	180° U.	23.67	41.52	24.5	51.83
D	4.25	0.40	0.82	180° U.	29.16	47.86	20.0	33.06
E	4.95	0.42	1.03	30° B.	33.05	60.09	2.0	3.71
F	6.42	0.52	0.92	10° B.	None detected	110.57	Nil	Nil
G	7.95	0.43	0.79	5° B.	None detected	77.38	Nil	Nil
H	12.22	0.41	0.85	10° B.	34.50	80.24	1.0	1.63
J	15.98	0.45	0.83	60° B.	28.53	80.24	5.5	7.33
K	10.91	0.41	0.96	180° U.	15.33	43.0?	55.0	63.11
1	2	3	4	5	6	7	8	9

TORSION TESTS		Compression at 100 Tons per Sq. In.	Modulus of Elasticity	SHOCK TESTS			HARDNESS TESTS		Brinell Ball Test Hardness N- (Normalized Specimens)
Twisting Moment	Angle of Twist at Fracture			Fall of 46.7 Lb. Hammer	Energy Absorbed	Bending Angle	Indentations in 1-1000 In.		
							Load in Tons 1.5	Load in Tons 2.5	
In. lb.	Deg.	Per cent	Lb. per sq. in.	In.	In. lb.	Deg.			
4,277	—	36.08	32,100,000	13.23	451	18.0	7.2	15.0	202
5,077	405	36.21	30,700,000	13.05	428	17.0	6.4	14.5	2?7
5,009	621	37.54	30,500,000	13.67	454	16.5	7.0	16.5	212
5,071	468	31.13	29,000,000	13.02	460	15.5	6.0	12.3	2??
6,420	177	6.64	29,500,000	13.67	217	Broken O	4.2	8.7	5??
7,407	42.6	5.73	28,000,000	13.07	105	Broken O	2.5	5.5	5??
7,038	20.1	3.57	27,300,000	14.15	230	Broken O	2.5	5.7	578
8,021	31.5	7.52	27,500,000	14.17	436	7.5	3.2	6.2	5??
7,320	118.5	0.31	27,400,000	13.33	432	14.5	5.0	10.3	203
5,662	690	20.94	29,600,000	13.77	452	28.0	10	40	113
10	11	12	13	14	15	16	17	18	19

In column 5, U. signifies unbroken; B., broken.

By taking the bending angle in conjunction with the energy absorbed, a very fair ideal of the properties of the steels under impact is obtained. These two sets of observations are plotted on Fig. 7, where it will be noted that the series of steels follow generally the order observed in the earlier tests.

Under hardness tests the first four alloys give nearly the same values. At 5 per cent nickel a marked increase in hardness is seen. The hardness reaches a maximum value at about 8

FIG. 4.—*Maximum Stresses and Twisting Moments.*
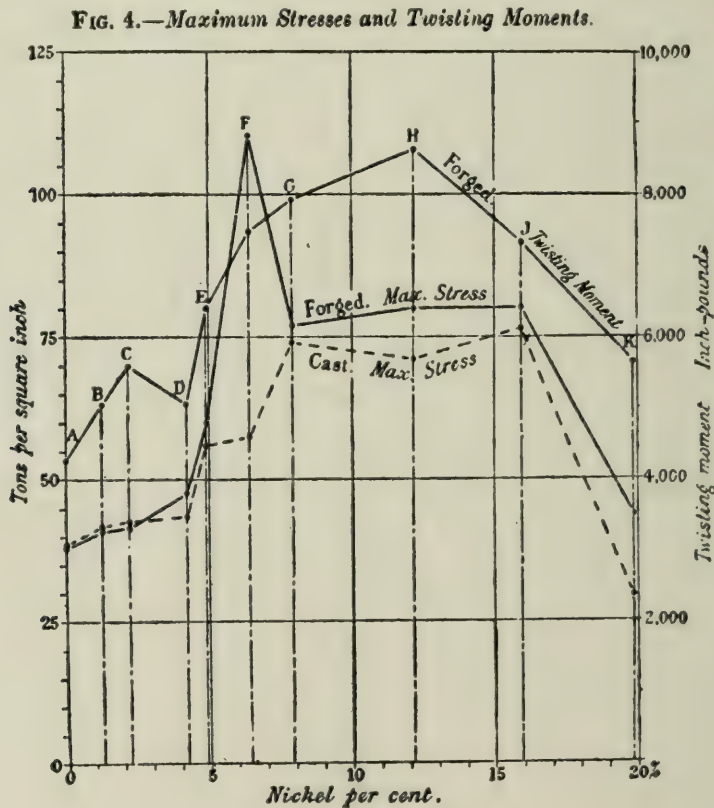
per cent nickel, the values over the range 6.5 to 12 per cent being, however, very similar. At 16 per cent a very marked drop occurs, and at 20 per cent the softest alloy of the series is seen.

General Summary of the Mechanical Tests. — Dealing with this series of tests of the different mechanical properties, it will be seen that they all give the same kind of result. With the introduction and increase of nickel content up to 4 per cent the change in the properties is gradual; the material, when under elastic stress, yields more to the stress; at the same time, after the apparent yield point is passed, the maximum stress

increases. Although the change of properties is gradual, there is in nearly every case a more or less pronounced kick in the curves between o and 4 per cent nickel. At some point between the percentages of 4.25 and 4.95 nickel, there is a very sudden change in nearly all the properties, evidenced by a rapid increase of maximum stress, which reaches the highest value at 6.42 per cent nickel, a fall of ductility, and an increase of brittleness, as shown by the bending, tension, torsion and shock tests. Thus, as far as industrial products are concerned, a danger limit for nickel content is found at $4\frac{1}{4}$ per cent, when carbon

Fig. 5.
Compression Tests.
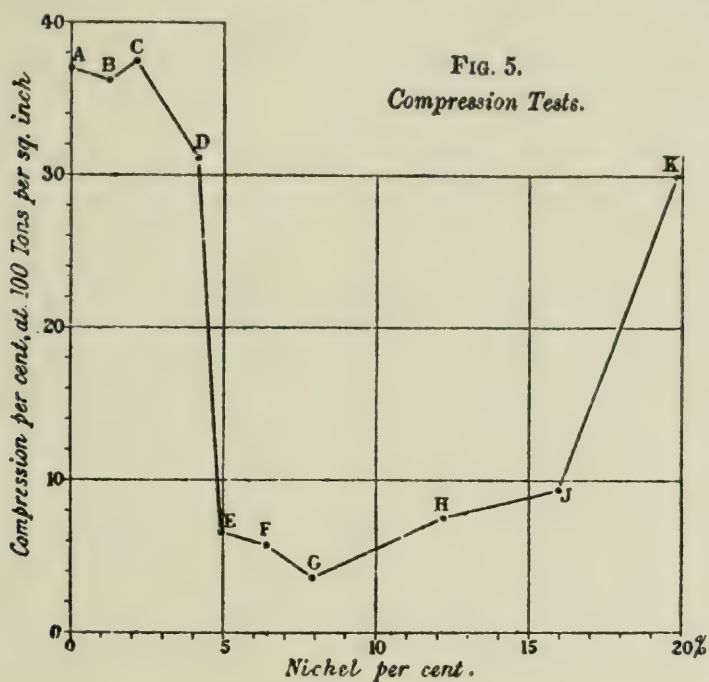
and manganese are present to the extent of .44 per cent and .88 per cent respectively.

After this sudden break in the curve, the various properties alter more slowly again until a percentage somewhere in the neighborhood of 16 is reached, *i. e.*, the brittle zone extends from about 5 to 16 per cent. From this point on, the change is more rapid, and in the reverse direction to the original rapid change. Fig. 1 is thus roughly typical of any of the curves.

MECHANICAL PROPERTIES OF THE CAST MATERIAL

These results follow generally the same order as those of the forged material, maximum tensile strength, however, being

represented at a content of 7.95 per cent nickel. Singularly enough, this maximum is associated with an elongation of $4\frac{1}{2}$ per cent, and the three steels, which in the forged condition are distinctly brittle, show in the cast normalized state elongations of 6.2, 4.5 and 6.2 per cent. These results are remarkable and unusual, but some analogy exists. Thus alloy H, 9.51 per cent nickel, in the forged annealed condition, fractures at an angle of 5 degrees; the same steel in the cast annealed state bends to an angle of 8 degrees. Somewhat similar results were found in the case of J, and it will be noted that, in bending, this steel in the unforged condition reaches an angle of 9 degrees, whilst in the forged state fracture occurs at an angle of 3 degrees. The compression results of J are also of interest, the cast unannealed alloy shortening some 5 per cent, whilst the forged unannealed shortens only 1 per cent at 100 tons per square inch.

Physical, Chemical and Metallographical Properties

The results of the electric resistivity tests are plotted in Fig. 7, the coördinates being resistivity and percentage nickel. The resistivity rises with ascending nickel, the values for alloys A–D, H, J and K lying practically on a smooth curve. Alloys E, F and G give values above the smooth curves. These values have been doubly checked. The sudden change at E is coincident with a structural change in the series, and constitutes pdditional evidence of the sharp break in the continuity of the aroprteies of the series which is manifested in the great majority of tests made.

Amongst the most interesting of the tests were those for corrosion, which were carried out on pieces of the $\frac{1}{2}$-inch diameter forged bars in two ways.

(*a*) Immersion in well-aerated fresh water ⎱ at ordinary
(*b*) Immersion in 50 per cent sulphuric acid ⎰ temperatures.

The tests under (*a*) were carried out to get some idea of the extent of fresh-water corrosion under " natural " conditions; those under (*b*) to enable a comparison to be made with the behavior of low carbon nickel-iron alloys.

Fresh-Water Corrosion Tests.—The specimens weighed about 70 to 80 grams each. They were suspended by string in separate glass pots filled with water. The latter was renovated each

day, and the film of brown hydrate gently brushed off. The pots stood beside an open window, night and day.

Duration of test, 32 days.

At the completion of the test, the brown scale was removed as far as possible by careful rubbing with fine emery paper. The bars were heated for $1\frac{1}{2}$ hours at 110° C. to 120° C., — 230° F. to 248° F., — allowed to cool in a desiccator and weighed. The losses in weight ranged from .07 to .1 of a gram. The per-

Fig. 6.—*Impact Tests.*
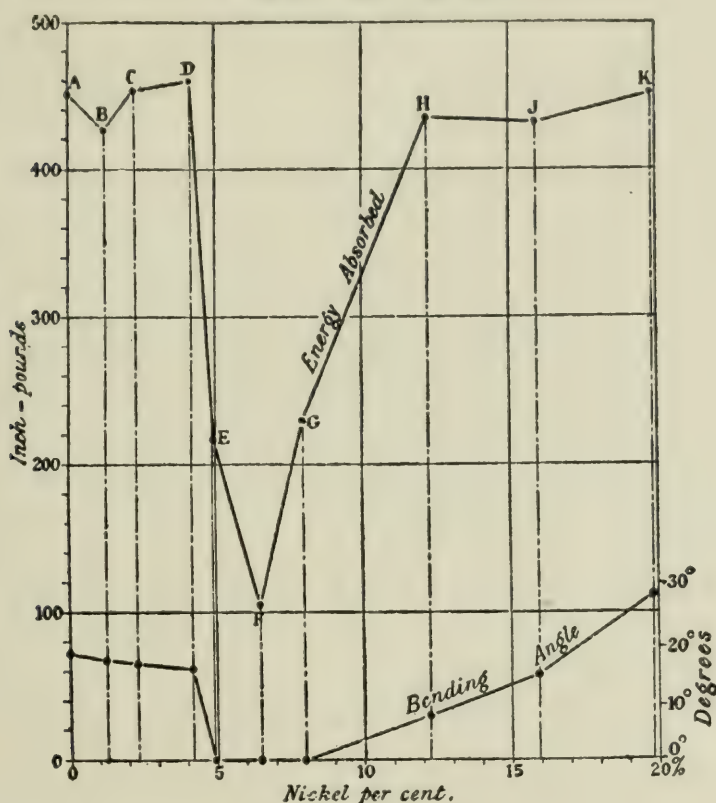
centage losses ranged from .15 to .09 per cent. The differences found are very slight, but they tend to show that from 12 per cent nickel upwards the tendency to corrode under these conditions diminishes.

Sea-Water Corrosion Tests. — These were carried out under conditions similar to those described for the fresh-water corrosion tests. The duration of the test was thirty-three days, and the sea water was changed once a week. The losses in weight varied from .11 to .22 of a gram. The percentage losses are

about twice as great as in the case of the fresh-water tests, and they agree with the latter in indicating that up to .12 per cent nickel no marked difference of behavior is exhibited by the alloys, and that with higher percentages of nickel the tendency to corrode is less marked.

Acid Corrosion Tests.—The bars used in the previous experiments were afterwards immersed, each in a separate trough, and supported at two points on thin glass rods, to enable the liquid to circulate round the bar in acid — at the ordinary tem-

FIG. 7 .—*Resistivities.*

Nickel per cent.
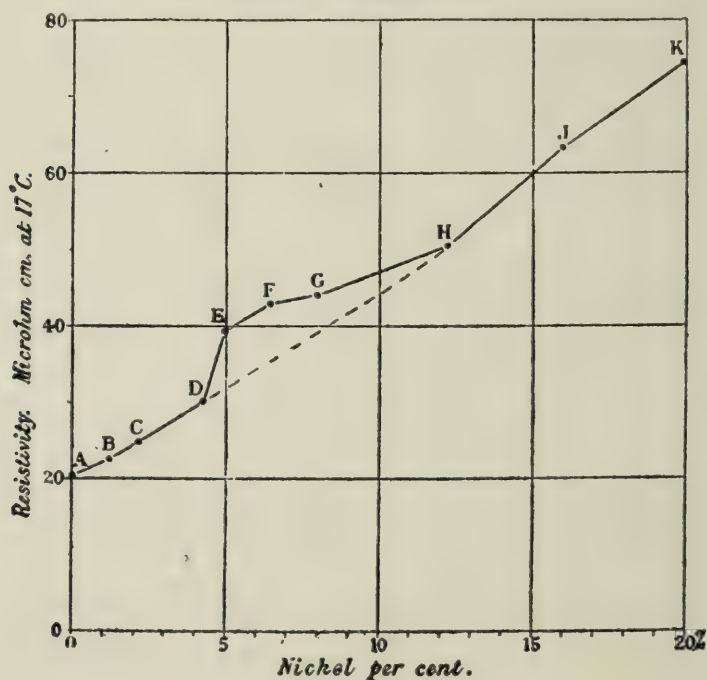
peratures — made by mixing equal volumes of distilled water and concentrated sulphuric acid.   More than sufficient acid was present to dissolve the whole of each bar.   A vigorous action soon set in with the early members of the series, the gas evolution being less marked among the later members.   As time went on, bars A–H gradually became coated with a deposit of white salt. This was probably a mixture of anhydrous sulphates, insoluble in sulphuric acid.   After a fortnight the powders were broken off, and the liquids well stirred.   After seventeen days the reaction had practically ceased among the early members.   The bars were then taken out, washed, dried at 120° C. (248° F.),

cooled in a desiccator and weighed. The losses in weight ranged from about .21 to .88 grams. The percentage losses vary between 1.10 (B) and .28 (J and K).

Except for a rather high corrosion figure for B, the values decrease fairly uniformly with ascending nickel. The irregularity at B will have been noticed in various mechanical and physical tests. The differences in the structural characters of the alloys render these differences of behavior towards attacks by acid quite intelligible. In the solution in acids of the pearlitic alloys with duplex structure, differences of potential are probably set up, which doubtless facilitate the attack. In the polyhedral alloys, on the other hand, where the structure appears

FIG. 8

Corrosion Tests.
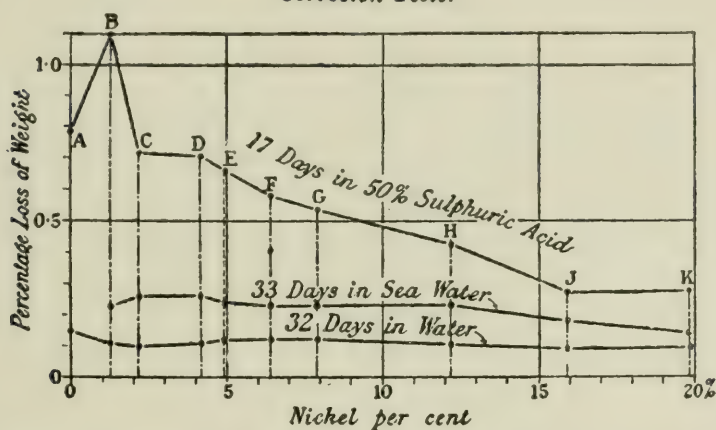
to be homogeneous, such differences of potential cannot occur, and solution will be more difficult. The results are plotted in Fig. 8.

The remainder of the paper is devoted to an exhaustive inquiry into the critical ranges on cooling and heating, and the metallography of the alloys. It defies abstraction, and is too long to reproduce in full. An important conclusion, which refers, we understand, specifically to K, but has doubtless a general application, is as follows:

Summarizing the results, it is seen that the structures induced by (*a*) forging, (*b*) bending and (*c*) compressing, which deformed the bars, however, without fracturing them, can be removed, and the original types reverted to, by a short heat treatment at 800° to 900° C. (1472° to 1652° F.); while the structural results produced by stresses, which caused fracture,

are not so easy to remove. However, in the case of the forged tensile and torsion sections, there was an appreciable reversion in parts towards the original polyhedral structure. It seems probable, therefore, that a prolonged heat treatment, at a temperature of about 900° C. (1652° F.), would cause a complete restoration in every case.

The authors' results are thus not in agreement with those obtained by M. Guillet, who affirms that " a steel which has once been changed from the polyhedric to the martensitic condition, by whatever method, cannot be regenerated either by annealing or quenching."

SOLUTIONS OF SOLIDS AND SOLID SOLUTIONS *

By J. H. STANSBIE, B.Sc., F.I.C.

THE general question of solution has always been of importance to the metallurgist, and is becoming more so on account of the fresh information concerning the nature of solutions which is constantly coming to hand. The practical metallurgist has so many difficulties to overcome in the melting, casting and manipulation of metals and alloys generally, that information which seems to have but a remote bearing upon his work may prove useful, and he cannot afford to let it pass.

Solids and liquids are recognized by their general properties, and it is certain that whatever matter is, a solid body of appreciable size is made up of parts, and that there are causes within the body which determine the relative positions of these parts, and also their mean distance apart. This may be explained by assuming that internal friction prevents the separation of the parts, or that there is a constantly acting pressure which is directed towards the interior of the solid. The idea of internal friction is supported by the viscosity of the malleable metals, which enables them to flow under the hammer. But in order that this change in form may take place, work must be done upon the metal, and in this respect the viscous solid differs from the true liquid, which can alter its form without expenditure of

* Abstract of paper read before the Metallurgical Society at the Birmingham Municipal Technical School, November 11, 1905, " Engineering," January 5, 1905.

work, if allowed to do so. It will be well to keep this viscosity of metals in mind, and to remember that for the majority of metals there is a temperature at which the metal offers the least resistance to work done on it while still preserving the solid state.

Also, it may be noted that the work put on to a solid during its change of form may all be converted into heat, or part of it may be stored up in the body itself. The latter is the case with metals which harden when they are worked, and the fraction of the energy thus stored up is given out again during annealing. Thus the system " hard metal " contains more energy than the system " soft metal."

Generally speaking, the particles of a solid are under restraint, and their separate motions are confined to excessively small spaces; but in a liquid there seems to be nothing to quite hinder its particles from wandering anywhere within the boundaries of its volume. There is, however, a cause which determines the mean distance of these particles, and so determines the volume of the liquid. It is well known that an enormous pressure is required to reduce the volume of a solid or liquid when it is a true volume pressure — that is, directed from all parts towards the center of the body; although the density of a metal may be increased by working.

Now we may regard any solid or liquid body as a self-contained system which will conserve itself as long as neither matter nor energy crosses its boundary, although the relations between its matter and energy may undergo readjustment. But if energy enters or leaves such a material system, important changes may take place. The changes we have to consider refer to the solid and liquid states.

Solids may be divided into two classes, — amorphous and crystalline. Amorphous means without form, in the sense of without crystalline form. Amorphous solids seem to come more into a line with liquids. They certainly resemble ordinary liquids in viscosity, although their viscosity is much greater than that of water. There is a tendency to wander on the part of the individual particles; but whether it takes place at ordinary temperatures, even to a limited extent, is an open question. Although Ewing and Rosenhain and Stead have observed the gradual absorption of one solid body by another, such solids have the same properties in all directions; that is, the forces at work

within them are evenly distributed, and wandering is thus probable; for any slight disturbance of the equilibrium in any part would tend to set up motion in that part. This inclines us to the belief that metals which become plastic on heating lose their crystalline character when in the plastic state, and those that harden on working also tend to become amorphous. In a crystalline solid, however, there is no haphazard arrangement of the particles. The form of the ultimate particles or molecules seems to condition the regular arrangement, and the regular, though not always uniform, distribution of the internal forces.

Now if we agree that an amorphous solid resembles a liquid, it must also resemble a liquid solution; and if it resembles a liquid solution, it must also resemble a solid solution. May it be said, then, that a solid solution is amorphous?

But it is possible for an amorphous solid to crystallize under proper conditions; it is also possible for a solid solution to crystallize. Is it still a solid solution after the crystallization has taken place? The answer to this is, that mixed crystals are regarded as solid solutions. What is the solution of a solid? If a solid combines with a liquid to form a homogeneous mass — that is, a mass of uniform concentration, which is still liquid — the whole mass is called a solution of the solid, and the components of the solution are known as the solvent and the solute. In such a mass there is a complete merging of the components without regard to that fixed ratio between them which is so characteristic of a true chemical merging. In the process of solution the solid disappears from sight, even when aided by the most powerful microscope, and the most careful analysis fails to detect any difference in composition of different parts of the solution.

From what has been said already, it will be understood that a kind of internal pressure is acting towards the interior of a solid, so as to keep its mass intact without aid from outside. You may call this attraction, cohesion, tenacity, or give it any name you please, but the fact remains that an expenditure of energy is necessary to separate its particles.

In the liquid state the body is in a more unstable condition, for in many cases its exposed surface loses some of its matter under certain conditions; but even this depends upon the readi-

ness with which the liquid becomes gas. But as it loses matter it also loses internal energy.

Now in the case of liquids a small portion of their internal energy seems to concentrate itself very near to the boundaries of the body. This is known as superficial energy, and its amount depends upon the area of its surface, and the bodies with which it is in contact. It appears to act in a very thin stratum, and is known as surface tension. This surface energy always tends to a minimum, and seems to act as a kind of pressure towards the interior when it is allowed full play. This is seen in the case of raindrops, which are masses of water occupying volumes with the smallest possible areas under the conditions. Here the surface tension causes the boundary layer to act like an elastic skin, and to draw the matter into its volume of smallest area.

A homogeneous solid or liquid is said to be in a definite phase, and it is immaterial how many components there may be in the mass as long as it is homogeneous. Another idea of a phase is that it is a mass of uniform concentration, and when it consists of more than one component they are mechanically or physically separable.

A system consisting of one or more phases is said to be in true equilibrium when it remains constant under constant conditions of temperature, pressure and concentration, and when a very small change in one of these variables causes a correspondingly small change in the system.

Now turn to a system consisting of a solid and a liquid which will dissolve it. If there is an excess of the solid, the point of saturation for a definite temperature cannot be exceeded, however long the solid and liquid phases are in contact with each other. The two variables here are the temperature and concentration.

Let us consider for a moment what is happening here. We know that the solid phase is passing into a liquid phase; and we know further that it is a purely physical or mechanical action, and that heat is being absorbed. Now it is purely a surface action. The particles of the solid are in contact with the particles on the surface of the liquid, and their proximity assists in some way, it may be by surface tension, the internal energy of the solid, which is always directed outwards, and some of the solid particles find themselves in the liquid. But these particles

still have a tendency towards their own, and although they have become migrating bodies, they sometimes migrate back, and an interchange may take place between the particles of the solid in the liquid, and these in the solid itself. This goes on till the point of saturation is reached, and then the rate of exchange of particles is the same in all directions, and we have a system consisting of a solid phase and a liquid phase in equilibrium. The solid phase consists of one component, and the liquid phase of two components, the liquid and the solid dissolved in it.

The rate at which a given solid dissolves in a given liquid depends upon a number of circumstances. Sometimes it is very rapid, and sometimes very slow. Also the rate at which the solid particles will diffuse through the mass of the solvent may vary considerably.

It may be remarked that the idea of interchange or dynamic equilibrium between the solid and liquid phases after saturation has been reached appears to be opposed to that of uniform concentration; but it may be said that this exchange takes place only in the surface layers, and is of a constantly counter-balancing character. The necessity of the idea is shown by the fact that large crystals in a saturated solution may grow on one face and dwindle on another to exactly the same amount, the total mass of the crystal keeping constant. This is probably due to slight differences in the concentration of the layers in contact with the faces, which causes a difference in the surface energy on the faces. But as these differences may be excessively small, the general concentration may be regarded as uniform. The general principle contained in this statement is of importance in connection with solid solutions. There is also the view that the crystals may have different solubilities in different directions.

The equilibrium of the system solid solution is at once disturbed by an increase or decrease in its temperature. The general effect of an increase in temperature is to cause more of the solute to pass into the solvent, and a decrease to bring about the opposite effect. But this is not uniformly true, for the solubility of some solids increases with the temperature up to a certain point, and decreases with a further increase in temperature.

A solid in solution possesses a definite pressure which is called its solution pressure; this is no doubt largely instrumental

in bringing about diffusion of the solid through the bulk of the liquid after dissolution. It is well known that a salt in solution raises the boiling point of the liquid, and this means simply that a given rise in temperature causes a smaller increase in the vapor pressure of the solvent when a solute is present than when it is absent. Also, the freezing point of the solution of a solid is lowered by the presence of the solid; the lowest temperature being obtained for a definite concentration, which, in the case of salts and water, gives the composition of the cryohydrate, and in the case of alloys, the eutectic mixture.

In many cases solutions can be cooled below their point of saturation without any of the solute separating in the solid state; but the system is in unstable equilibrium, and a small portion of the solid dropped into the solution causes partial solidification, with development of heat, to take place at once.

What is a solid solution? A solid mass containing two or more components of uniform concentration. In other words, it is a homogeneous mass containing constituents which are physically and mechanically separable as far as solidity permits. Here we have the possibility of variations in concentration with variations in temperature; also of conditions under which certain components are in equilibrium. But it is very evident that the investigations of such conditions are much more complicated than with solutions of solids. All changes in solid solutions must be necessarily slow.

The clear glasses are probably the best examples of solid solutions, for their composition may vary by infinitesimals from specimen to specimen. The readiness with which molten silicates dissolve either silica or basic oxides is well known, and also that the components may or may not be able to remain in solution when the molten mass solidifies. If they do remain in solution, then a solid solution results; but if not, a heterogeneous mass is obtained.

Mixed crystals are also examples of solid solutions. Such crystals are best studied with salts crystallized from aqueous solution, and the alums furnish good illustrations. It is quite easy to form mixtures of common alum and chrome alum in any proportions.

Now these solid solutions which partake of the nature of mixed crystals are of considerable importance from a metal-

lurgical point of view.   All metals are of crystalline nature, and
many of their crystalline forms belong to the cubic system —
that is, they are isomorphous, and, all other conditions being
favorable, should form mixed crystals.   Thus it may be stated
generally that, in the case of pure alloys of metals, the solid
solutions take the form of mixed crystals.   Gold and silver
alloys give the simplest cases of solid solution of metals of uni-
form concentration.   This is brought out by the freezing curve,
which, for a series of gold-silver alloys falls uniformly from the
freezing point of gold to that of silver.

It has been stated that solid solutions in the case of metals
are heterogeneous, on account of the slow diffusion which takes
place in the molten metals as compared with the solutions of
solids in liquids.   But it would appear that this is only a matter
of time, for if the alloy is kept molten sufficiently long, uniform
concentration may be attained, and then the slow motions of
the components in the solution would favor the retention of
uniform concentration in the alloy on freezing.   But another
aspect of the question arises when chemical compounds are
formed between two metals, or a metal and a non-metal.   In
this case any solution must be formed by the dissolution of the
compound in excess of the main mass of the metal.   A case in
point is found in the alloys of copper and arsenic.   Now there is
not the slightest doubt but that arsenide of copper is formed and
dissolved in the molten alloy.   Micro-examination of copper-
arsenic alloys shows that a separation takes place during the
solidification.   But it is probable that a certain percentage of
arsenic in the arsenide forms a solid solution, which has a much
less hurtful effect on the main mass of the metal than when a
eutectic separates.   This is a practical question of some impor-
tance to those who introduce small percentages of certain ele-
ments into copper to produce sound castings.   For it is clear
that the proportion of the added element should be about that
required to form the solid solution; and this for arsenic in copper
seems to be about .25 per cent of arsenic.

The relations of carbon to iron in alloys of these bodies have
formed the subject of an enormous amount of work, and many
investigators are still at work upon it.   The only reference I
wish to make to that work is in connection with the solid solu-
tions of carbon in iron which exists in hardened steel, and which

is known by the name of "hardenite," about which the last word has not been said. Now Howe states that solid solutions are heterogeneous, and probably bases his opinion upon a micro-examination of hardened steel; but is it necessary to assume this heterogeneous character from an etched specimen? A solid solution should etch uniformly, and that is the only condition necessary; for if an etching liquid is used, it attacks the component of the solid solution for which it has the greatest affinity.

METALLOGRAPHY APPLIED TO FOUNDRY WORK *

PART V

By ALBERT SAUVEUR

The Microstructure of Cast Iron

IN the first four installments of this article the apparatus and manipulations required to prepare, examine and photograph samples of cast iron with a view of studying their microstructure, have been briefly considered and I may now pass to a description of these structures.

It is well known that the carbon present in cast iron may exist in two distinct forms, (1) as free or " graphitic " carbon and (2) chemically combined with some of the iron forming the carbide Fe_3C, a compound which contains 6.67 per cent of carbon and 93.33 per cent of iron; and it is also well known that the physical properties of any cast iron depend primarily upon the relative amounts in which these two varieties of carbon are present.

In some cast irons the totality of the carbon may occur as graphite, while in others it may wholly be present in the combined form. Between these two extreme types numerous grades of cast iron exist containing both graphite and combined carbon in varying proportions, and with correspondingly varying physical properties.

Those cast irons which contain most of their carbon as graphite are called gray cast irons because of the dull gray or blackish appearance of their fracture, while those in which the whole of the carbon is combined are known as white cast irons because of the bright metallic luster of their fracture.

* " The Foundry," January, 1906.

The well-known causes to which the formation of these two distinct kinds of carbon are due will be alluded to on another occasion, it being desired for the present merely to describe the structure of these various grades of iron as revealed by the microscope.

The structure of a perfectly gray cast iron, that is, of an iron free from combined carbon, is shown in Fig. 1 under a magnification of 50 diameters.*   It will be found to consist of a number of dark, irregular areas embedded in a light background, the former representing the location of the graphite particles, the
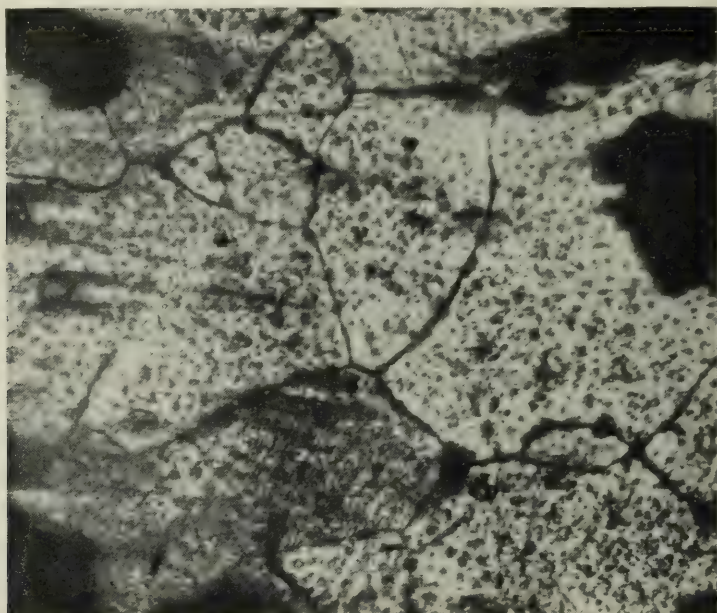
FIG. 1.   Gray Cast Iron from Salamander.
Magnified 50 diameters (etched).

latter representing the metallic iron.   It may at first sight seem surprising that so large an area should be occupied by graphite in view of the fact that the iron did not probably contain much over 4 per cent of graphite, but this will be readily explained, if it be considered that this means percentage in weight, while the

* As it was not possible to obtain a piece of gray cast iron absolutely free from combined carbon, we show here, for purpose of illustration, the structure of a salamander, that is, one of those masses of iron and carbon which frequently form in the crucible of blast furnaces, under conditions extremely favorable to the production of graphite and to the exclusion of combined carbon, namely, high silicon content and very slow cooling; such a metal may rightly be considered as an absolutely gray cast iron.

microscope reveals the volume or bulk of the various constituents, and because of its relatively low specific gravity the graphite will necessarily occupy a relatively large space.

Iron considered as a microscopical constituent is called " ferrite," and the structure of absolutely gray cast iron may then be described as consisting of a mass of ferrite in which are embedded numerous irregular particles of graphite.

It will be noticed in Fig. 1 that the etching treatment has resulted in resolving the ferrite into a number of irregular, polyhedric grains, giving to its structure a network appearance.
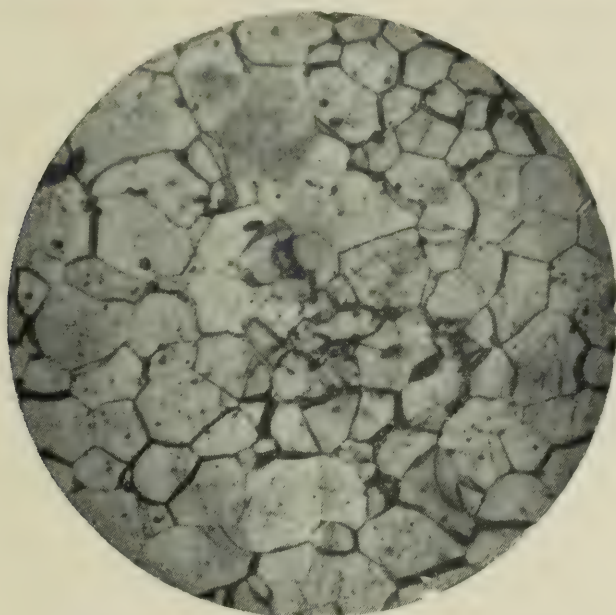
FIG. 2.   Carbonless Iron.   Magnified 50 diameters.

This network marks the junction lines between adjacent grains, the etching fluid having corroded the metal more deeply between the grains than over their surface.   Most of the grains are hexagonal, which strongly suggests that iron, like most metals, crystallizes in the regular cubic system, these hexagonal grains being probably due to interfering cubes and octahedra.

If we now examine the structure of pure iron, or, at least, of carbonless iron as shown in Fig. 2, the striking similarity between the structure of this metal and that of the metallic matrix of gray cast iron free from combined carbon (Fig. 1) will be apparent.   The ferrite which necessarily forms the totality of carbonless iron exhibits the network structure seen also in the matrix of the gray cast iron.   Both are made up of irregular, polyhedric

ferrite grains.   There is much structural resemblance, therefore, between perfectly gray cast iron and carbonless iron — and still their properties differ widely.   Gray cast iron, free from com-bined carbon, lacks strength, ductility and malleability, while carbonless iron is strong, ductile and malleable.   The reason for this difference must be ascribed to the presence of graphite in the gray cast iron, which by breaking the continuity of the metallic mass (the strong, malleable ferrite) greatly weakens it and destroys its original ductility and malleability, rather than to the weakness and brittleness of the graphite particles them-
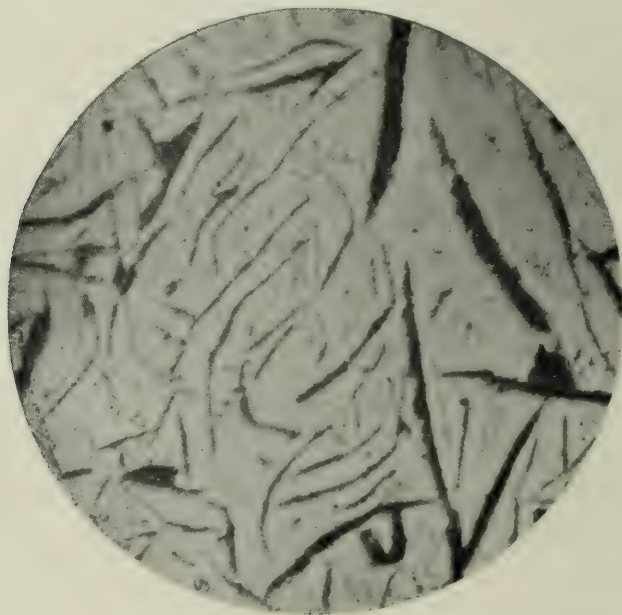
FIG. 3.   Highly Graphitic Cast Iron.   Magnified
50 diameters (not etched).

lelves.   If all the particles of graphite could be removed bodily, seaving in the iron the small cavities which they once occupied, it does not seem probable that the properties of the cast iron would be materially modified.

It will be apparent from these considerations that the more numerous the particles of graphite the more will they weaken and otherwise affect the properties of the ferrite in which they are embedded, and it will also be apparent that the shape and dimensions of the graphite particles must also have their influ-ence.   If the graphite could be made to occur in small, rounded particles it would probably affect the ferrite to a much less extent than when present, as is generally the case, in irregular and

curved plate. (See Fig. 3.) Indeed, this is strikingly borne out by the strength and ductility of malleable cast-iron castings in which small, rounded particles of graphite are embedded in a mass of ferrite, similar in every respect to the ferrite of gray cast irons, as will be shown on another occasion.

The foregoing considerations suggest three means of increasing strength of gray cast iron free from combined carbon: (1) By reducing the amount of graphitic carbon, (2) by decreasing the size of the graphite particles and (3) by regulating the shape of the graphite particles, causing them to occur as rounded grains rather than as curved plates.

FIG. 4. Salamander. Magnified 30 diameters (not etched).

The amount of graphitic carbon (which here means the amount of total carbon) can be decreased by the use of steel or other low carbon metal in the cupola, or by oxidation in the " air furnace."

The sizes of the graphite particles are undoubtedly greatly influenced by the rate of cooling of the castings during solidification and subsequent cooling, and this in turn is affected by the size of the castings. It is probably true that the slower the cooling during solidification and subsequent cooling the larger the graphite particles. In Fig. 4 is shown the structure of another salamander, formed in the crucible of a blast furnace magnified

only 30 diameters. The very large size of the graphite plates, caused undoubtedly by the extremely slow solidification and cooling of the iron, will be noted.

In the references which have been made here to the rate of cooling it has been supposed that the cooling could in every case be conducted so as to preserve the whole of the carbon in the graphitic condition. As is well known, however, a slight acceleration of the cooling will often suffice, even in the presence of a large amount of silicon, to cause the formation of some combined carbon, the iron then ceasing to be perfectly gray and acquiring properties due to the presence of combined carbon, which will be considered in our next installment.

No means have yet been devised for regulating the shape of the graphite particles which form during the solidification and cooling of gray cast iron, but it would be hazardous to affirm that no heat treatment or other manipulation can ever be found which would accomplish this end.

Very few castings, if any, are produced absolutely free from combined carbon, nor are they generally wanted because of their lack of strength, but it was desirable to start our description with the structure of such cast iron because it forms the first link of the chain uniting cast iron free from combined carbon with cast iron free from graphitic carbon, the various links of which are to be described in these articles.

ELECTROLYTICAL GALVANIZING *

By HENRY I. WHITE

WITHIN the past two years increased attention has been given to cold zincing or electrolytic galvanizing. This is not a new process, as it had been in successful use a long time previously, coating all kinds of iron castings, tubes, wire, sheets, etc. More particularly, however, has attention been given to this special branch of industry in Germany, Italy, England, Austria and Hungary. In the last named country the researches of Czermay have attracted considerable interest. In government yards, various shipbuilding establishments, tube and wire works, the results obtained have been so economical and gratifying to the users that hot galvanizing has been suspended.

The results that have been accomplished by Czermay on the theory of neutral baths have been amply confirmed by the splendid work accomplished by Prof. C. F. Burgess of our own country. They demonstrate that on the one hand electrolytic zincing resists atmospheric and other corroding influences much better than hot galvanizing, while on the other hand the cold process dispenses with the employment of the dross and skinning man and the man who is needed to keep the pots hot all the twenty-four hours, and further avoids the inevitable loss of pots and metal.

In order to convince parties who were more or less interested in this process, severe tests were made for lengthy periods on pieces of various articles coated by the cold process, such as wide variations of temperature, carbonic acid, sulphurous acid and humidity. To make these tests conclusive an atmosphere containing 15 per cent of carbonic acid (CO_2) and 12 per cent of sulphurous acid (SO_2) was artificially created, while the greatest proportion of these acids in the ordinary atmosphere does not exceed 0.03 per cent of CO_2 and 3 per cent of SO_2 even under the very worst conditions. The mechanical and chemical tests described below were made on articles galvanized by the hot process in England and Germany and those treated electro-

* "The Iron Age," January 18, 1906.

lytically came from different works operating under the Czermay process.

Mechanical Tests

A. ROOFING PLATES

1. *Bending and Folding.* — The corners were turned down and the metal was beaten flat on itself with a wooden hammer; then reversed and beaten flat on itself at the opposite side. Work was done on both sides at the same location. Other sheets were folded singly and doubled.

2. *Torsion Tests.* — The sheets were cut into small strips, then wound spirally.

3. *Tension Tests.* — The sheet strips were slowly stretched between jaws to 10 per cent above the original length.

The results were as follows:

TABLE I

Article	Bending and Folding	Torsion	Tension
A Sheets coated by hot process.	First bending, good. Second bending at same location, zinc scaled off. Single folding, good. Double folding, zinc came off in places.	Showed scaling on zinc.	Zinc flaked off.
A 1 Sheets coated cold, electro-lytically.	After two bendings and after two foldings on each side, the sheet showed no signs of failure.	No scaling at all.	Zinc kept on the stretched pieces.

B. TUBING

1. *Bending Test.* — Tubes $\frac{1}{2}$ inch to $1\frac{1}{2}$ inches outside diameter were fixed at one end in a vice and the opposite end was bent sharply around the vice.

2. *Hammering Test.* — The tubes were hammered at the point of weld until they split.

3. *Inside Test.* — The tubes were sawed lengthwise to show the interior coating.

The results were as follows:

<div align="center">TABLE II</div>

Article	Bending	Hammering	Interior
B Tubes coated by hot process.	Stood no bending. See remarks.	Broke like cast iron. Zinc scaled off in places.	No coating in many places.
B 1 Tubes coated cold electrolytically.	Showed perfect coating both inside and outside.	Separated at the point of weld in a straight line but zinc adhered.	All sizes showed perfect coating inside.

<div align="center">C. IRON AND STEEL WIRE</div>

1. *Bending Test.* — All the wire, No. 12 gauge, was wound spirally with force into a very tight loop, then unwound and reversed into a loop. Other pieces were wound around their own diameter in tight spirals.

2. *Torsion Test.* — The stretched wires were turned around their own axes and deformed.

3. *Tension Test.* — The wires were stretched 20 per cent above their original length.

4. *Hammering Test.* — The wires were flattened to one half their original diameter.

The results were as follows:

TABLE III

Article	Bending	Torsion	Tension	Hammering
C Wire coated by hot process.	First bending good. Second bending, zinc partly disintegrated.	Zinc scaled off.	No zinc on elongated pieces.	No zinc on hammered pieces.
C 1 American and English steel wire coated by hot process and wiped.	First and second bendings very good. When wound spirally zinc came off at places.	Zinc scaled in spots.	Zinc adhered on elongated portions.	No zinc on hammered pieces.
C 2 Wire coated cold, electrolytically.	First and second bendings faultless; spirals also; zinc adhered.	Zinc coating perfect.	Zinc on all elongated portions.	Thin zinc coatings on hammered portions.

After each test the respective pieces were dipped for a moment in a solution of sulphate of copper, then rinsed in water and wiped dry, in order to determine on the coppery places the exact extent of the zinc disappearance.

Parallel tests with black and galvanized tubes of the same make were conducted, which showed that the tubes galvanized by the hot process had undergone a molecular change in the structure of the iron, probably due to rapid cooling after subjection to a high temperature. This had the effect of making the tubes brittle, and in a galvanized state they would not stand the bending and hammering tests, whereas in the electrolytic process the iron suffered no such deterioration.

The inside coating of the tubes showed serious defects in the case of the hot galvanized, which became more apparent in tubes of smaller diameter, where, with the exception of small lists and streaks of molten zinc, no inside coating could be found; whereas all the tubes galvanized electrolytically showed in every case a faultless and complete inside coating.

CHEMICAL TESTS

The tested pieces consisted of strips cut from the sheets, sections of the tubes cut from the center, and pieces of wire cut from the coils.

It should be stated that the method generally in use for effecting rapid corrosion gives no indication as to the durability and resistance to corrosion of galvanized articles when exposed to atmospheric action. The immersion in a saturated solution of sulphate of copper or in a solution of normal sulphuric acid simply shows to what degree these sulphates attack and dissolve the zinc. Since these sulphates are not present in the air, no conclusion can be formed as to the corrosive action of the atmosphere on galvanized iron.

The above mentioned tests are all the more misleading, as iron coated with lead, tin or nickel will stand any number of such immersions without the steel or iron appearing, although the three metals named, in consequence of their electro-negative nature, afford no protection against corrosion, and goods coated with them, when exposed to the action of the air, corrode very quickly. It was thought proper, therefore, to provide such tests and to expose the tested articles to such influences as really

prevail in the atmosphere, which are variation of temperature and the presence of carbonic acid, sulphurous acid and humidity. These results are given in Table IV.

Remarks on the Above Results

The articles galvanized by the hot process showed a change during exposure, namely, a blackish appearance.

After exposure in the apparatus, all samples were further exposed to the action of air in a works yard.

A, B and C, after three weeks' exposure, bore traces of scaling on the parts where the zinc was still visible, through corrosion from the inside to the outside.

C 1 was entirely rusted after two weeks.

A 1, B 1 and C 2 showed, on the places where no dipping had taken place, that the surface was intact or a perfect zinc coating remained.

This demonstrated the value of the testing method.

It is interesting and instructive to compare the results of dipping C 1 in a fresh state and after it had been exposed. In the fresh state $2\frac{1}{4}$ dippings were obtained, after which the largest part of the wire showed a copper coating. But after it had been exposed the zinc was totally eaten away, and what remained of the coating was lead and other impurities, which, untouched by the sulphate of copper, could not protect the underlying steel wire from corrosion in 14 days when exposed in the fresh air.

The above experiments clearly demonstrate the worthlessness of the usual dipping test.

Conclusions

The above tests prove convincingly that steel and iron articles coated by the electrolytical process are superior to those galvanized by the hot process in their resistance to mechanical as well as to atmospheric action.

1. Whereas, in the hot process, in consequence of the unavoidable impurities of the zinc, large quantities of zinc must be applied to insure protection against corrosion, a very much thinner electrolytical zinc deposit will equally well and even better protect the goods because of its chemical purity.

2. In the hot process the larger quantities of zinc and the

unevenness of the coating injure the solid adherence, and since sheets, tubes and wire are worked up when used, a premature corrosion takes place on the worked-up spots. In the last few years an effort has been made to overcome this serious drawback by the wiping process, especially in the case of wire. A certain economy in the use of zinc is effected and greater uniformity and adherence of the coating are obtained (see C 1 in Table III of mechanical tests), but very much to the detriment of protection against corrosion, as the chemical tests will prove. The tested wiped wire was obtained from English and American works of world-wide repute, and it is clearly demonstrated by these tests that notwithstanding their bright appearance and greater flexibility they most decidedly are not proof against corrosion, as many consumers have found out to their cost.

3. In consequence of the use of ammonia and chloride of zinc, these being unavoidable in the hot process, the coating corrodes in case of mechanical injury, and the combined salts cause corrosion from inside to outside, notwithstanding the thick zinc coating, which, as shown in the tests, stood a high number of immersions.

None of these defects appear in electrolytical galvanizing, which for these reasons alone is preferable to the hot process. It is, however, a matter of great importance that the solution used in electrolytic baths be of a nature to give a really non-porous, consistent and durable coating, unadulterated by deleterious metals and strong acids, which will in every case cause corrosion, as explained above.

All the above tests were made on a commercial scale at works where the Czermay process is in operation. Materials galvanized under this process have been exposed for years and are to-day in perfect condition.

Table IV

Article	Average Weight of Zinc Deposit	Minutes Immersed before Exposure	Remarks	Minutes Immersed after Exposure	Remarks
A Sheets coated by hot process.	0.359 oz. per square foot single surface.	6	After immersion zinc remained "in some places, with numerous black spots.	3	Same as in Col. IV, only the number of black spots considerably increased.
A 1 Sheets coated cold electrolytically.	0.215 oz. per square foot single surface.	4	After immersion coherent zinc coating with exception of edges.	$2\frac{1}{2}$	Same as in Col. IV.
B Tubes coated by hot process.	0.337 oz. per square foot surface.	Outside $4\frac{1}{2}-5\frac{1}{2}$ Inside $\frac{1}{2}-1\frac{1}{2}$	Inside dippings refer to tubes $\frac{3}{4}$-in. and upwards only. Those of smaller diameter showed no zinc after $\frac{1}{2}$ minute.	Outside 2 Inside o	Zinc adhered on the outside, and black spots inside; no trace of zinc with exception of pieces of list.
B 1 Tubes coated cold electrolytically.	0.219 oz. per square foot surface.	Outside 5 Inside 4	After immersion zinc in places.	Outside $3\frac{1}{4}$ Inside $2\frac{1}{4}$	Same as in Col. IV.

10

TABLE IV—*Continued*

Article	Average Weight of Zinc Deposit	Minutes Immersed before Exposure	Remarks	Minutes Immersed after Exposure	Remarks
C Wire coated by hot process.	0.550 oz. per pound.	4	After immersion zinc in places on dipped spots.	2	Same as in Col. IV.
C 1 Wire coated by hot process and wiped.	0.30 oz. per pound.	$2\frac{1}{4}$	After immersion zinc in places on dipped spots.	6	After first immersion: no trace whatever of zinc, but no copper skin even after sxth immersion.
C 2 Wire coated cold electrolytically.	0.20 oz. per pound.	2	After immersion zinc in places on dipped spots.	$1\frac{1}{2}$	Same as in Col. IV.

THE BESSEMER PROCESS IN THE UNITED STATES*

THE recent occurrence of the semi-centennial of the invention of the Bessemer process justifies the following compilation, from our " Iron in All Ages," of the history of the introduction of the process into our own country. Mr. Bessemer's first public account of his invention was read by him at the annual meeting of the British Association for the Advancement of Science, at Cheltenham, in August, 1856. It was entitled, " On the Manufacture of Malleable Iron and Steel without Fuel," but his first English patent in connection with his great invention was granted on October 17, 1855. In 1856 he patented his invention in the United States, but he was at once confronted with a claim of priority of invention by William Kelly, of Eddyville, Ky., which was allowed by the Commissioner of Patents.

As early as 1861 Capt. E. B. Ward, of Detroit, and Z. S. Durfee, of New Bedford, obtained control of the patents of William Kelly, who had previously successfully experimented with the pneumatic process at Eddyville, where he owned the Eddyville Iron Works. In 1861 Mr. Durfee went to Europe to study the Bessemer process. During his absence Captain Ward invited William F. Durfee, also of New Bedford, and a cousin of Z. S. Durfee, to erect an experimental plant at Wyandotte, Mich., for the manufacture of pneumatic steel, and this work was undertaken in the latter half of 1862.

In May, 1863, Daniel J. Morrell, of Johnstown, and William M. Lyon and James Park, Jr., of Pittsburg, having become partners of Captain Ward and Z. S. Durfee in the control of the patents of Mr. Kelly, the Kelly Pneumatic Process Company was organized, Mr. Kelly retaining an interest in any profits which might accrue to the company. It was resolved to complete the experimental works already undertaken and also to acquire the patent in this country of Mr. Mushet for the use of spiegeleisen as a recarburizing agent. This patent was granted in England in 1856 and in this country in 1857. Mr. Z. S. Durfee accordingly went to England to procure an assignment of Mr. Mushet's patent. The latter purpose was effected on the 24th of October,

* " The Bulletin," American Iron and Steel Association, January 20, 1906.

1864, upon terms which admitted Mr. Mushet, Thomas D. Clare and John N. Brown, of England, to membership in the Kelly Process Company. On September 5, 1865, the company was further enlarged by the admission to membership of Charles P. Chouteau, James Harrison and Felix Vallé, all of St. Louis. In September, 1864, William F. Durfee succeeded in making Bessemer steel at the experimental works at Wyandotte. This was the first Bessemer steel made in the United States. A part of the machinery used at the Wyandotte works was an infringement upon Mr. Bessemer's American patents.

The control in this country of Mr. Bessemer's patents was obtained in 1864 by John F. Winslow, John A. Griswold and Alexander L. Holley, all of Troy, N. Y., Mr. Holley visiting England in 1863 in the interest of himself and his associates. In February, 1865, Mr. Holley was successful at Troy in producing Bessemer steel at experimental works which he had constructed for his company at that place in 1864. Mr. Mushet's method of recarburizing melted iron in the converter was used at Troy, and this was an infringement upon his patent in this country.

As the Kelly Process Company could not achieve success without Mr. Bessemer's machinery, and as the owners of the right to use this machinery could not make steel without Mr. Mushet's improvement, an arrangement was made by which all the American patents were consolidated early in 1866. Under this arrangement the titles to the Kelly, Bessemer and Mushet patents were vested in Messrs. Winslow, Griswold and Morrell, the first two being owners of seven tenths of the property and Mr. Morrell holding the other three tenths in trust for the Kelly Process Company. This arrangement continued until the formation of the Pneumatic Steel Association, a joint stock company, organized under the laws of New York, in which the ownership of the consolidated patents was vested. Z. S. Durfee acted as the secretary and treasurer of the company. The ownership of the patents was afterwards vested in the Bessemer Steel Company, Limited, an association organized in 1877 under the laws of Pennsylvania. This association was succeeded by the Steel Patents Company, organized in 1890. All the original English and American patents have expired.

William F. Durfee has described in the following words the quality of the Bessemer steel first made at Wyandotte: " Various

experiments were tried to test the ductility and working qualities of the steel produced at Wyandotte. Some of the early product was sent to Bridgewater, Mass., and there rolled into tack plate and cut into tacks which were pronounced to be very much superior to any previously made of iron. In order to test the welding qualities of the steel, John Bishop, the blacksmith of the works, made a tobacco-pipe the size of an ordinary clay pipe, the bowl and stem of which were welded up of Wyandotte steel, and when perfectly polished there was no visible evidence of a weld. I have now two jackknives and a razor made from this steel; the knives are rather soft, but the razor was used regularly by my father for fifteen years to his entire satisfaction.''

The consolidation in 1866 of the various interests above mentioned was followed by a large reduction in fees and royalties, and thenceforward the business of making Bessemer steel was rapidly extended in this country, although it is a remarkable fact that from 1876 to 1881 no Bessemer steel works were established in this country. Beginning with the latter year, many Bessemer works have been built in the United States, but these we need not mention.

Robert W. Hunt informs us that the first Bessemer conversion made at Troy was from Crown Point charcoal pig iron, melted in a reverberatory furnace, and William F. Durfee informed us years ago that the first steel made at Wyandotte was converted from Lake Superior charcoal pig iron, also melted in a reverberatory furnace, although on a number of subsequent occasions the metal for conversion was taken directly to the converter from the Eureka charcoal blast furnace at Wyandotte.

It is supposed that the first attempt made in the world to melt pig iron in a cupola for conversion into steel by the Bessemer process was made by Z. S. Durfee at the works at Wyandotte during the spring of 1865. This attempt failed of success owing to the small size of the cupola and the length of time required to accumulate enough iron in the traveling ladle for use in the converter; but the subsequent general employment of the cupola whenever pig iron was used for conversion into Bessemer steel is sufficient evidence that the thought which prompted this first experiment had a substantial and practical foundation. Mr. Hunt states that on July 20, 1865, Mr. Holley successfully used the cupola at Troy in connection with the Bessemer process.

The English practice at this time was to use the reverberatory furnace.

The first Bessemer steel rails ever made in this country were rolled at the North Chicago rolling mill on the 24th of May, 1865, from ingots made at the experimental steel works at Wyandotte under the supervision of William F. Durfee, superintendent. The rolls with which the steel rails were rolled at the North Chicago rolling mill had been in use for rolling iron rails. The steel rails came out sound and well-shaped. Several of these rails were laid in the track of one of the railroads running out of Chicago and were still in use in 1875. The American Iron and Steel Association was in session at Chicago at the time, and several of its members witnessed the rolling of the rails.

The first steel rails ever rolled in the United States upon order, in the way of regular business, were rolled by the Cambria Iron Company, at Johnstown, Pa., in August, 1867, from ingots made at the works of the Pennsylvania Steel Company, near Harrisburg, Pa., and by the Spuyten Duyvil Rolling Mill Company, at Spuyten Duyvil, N. Y., early in September of that year, from ingots made at the Bessemer steel works at Troy, N. Y., then owned by Winslow & Griswold.

Important improvements upon Mr. Bessemer's machinery were soon invented and patented by A. L. Holley, George Fritz, Robert W. Hunt, William R. Jones and other American engineers. Of these improvements the most notable is the Fritz blooming mill, which is in general use in this country and in Europe. The largest number of improvements were made by Mr. Holley. The inventive genius and rare mechanical skill of John Fritz, of the Bethlehem Iron Company, have also produced many valuable improvements which were clearly patentable but were not patented.

In the early stages of the Bessemer steel industry in this country great difficulty was experienced in obtaining suitable pig iron and also materials for the lining of the converters. Large quantities of Bessemer pig iron were annually imported. Our manufacturers were uncertain whether American ores would make good Bessemer pig iron, and many failures occurred in using domestic pig iron that was unsuited for conversion into steel. The lack of skilled workmen was also severely felt. All difficulties, however, have long been overcome. It is now

universally admitted that in the United States this industry has been brought to a higher state of perfection than it has attained in any other country. The American Bessemer steel works have been constructed after plans which are in the main greatly superior to those of European works. The United States is now not only independent of other countries for its supply of Bessemer pig iron but it is also the largest producer of Bessemer pig iron in the world.

The establishment of the Bessemer steel industry in many countries is justly regarded as constituting a much more important revolution in the production and use of iron and steel than had been created by any preceding influence or combination of influences in any age of the world's history. And yet this great industry did not for many years after it was established in Europe attract the attention either on that continent or on this which its importance deserved. In his report on the Paris Exposition of 1867 the Hon. Abram S. Hewitt said: "In view of the small amount of Bessemer steel as yet produced in the United States we are struck in Europe with surprise at the enormous provision made for its supply; and it is quite evident that the business is overdone, and, contrary to all past experience, the inventor and the public at large seem to have profited by its introduction at the expense of the manufacturer."

CORROSION OF FENCE WIRE *

A N investigation into the causes of the corrosion of wire used for fencing has been under way for some time by the Department of Agriculture, says the "Metal Worker." The results of the investigation up to date indicate that the causes of fence wire failures are not perhaps greatly different from those leading to deterioration of terneplates for roofing purposes. While the investigation in question has had nothing to do with the tin plate matter, the intimate relation of the subject will make the following report of the results of the investigation of timely interest. The work has been carried on under charge of Allerton S. Cushman, assistant director of the office of public roads.

* "The Iron and Machinery World," January 27, 1906.

The earlier correspondence that was carried on in the effort to get at the facts showed that a great many farmers believed that the manufacturers have neither the intention nor the desire to make the best possible wire. On the other hand, some manufacturers held that if it were possible to make a higher grade of wire at even a slightly higher cost it would be useless to attempt it, as the farmer desired cheapness above every other consideration. It is safe to say that neither of these extreme views has been substantiated by the evidence gathered during the progress of this investigation. The majority of farmers in this country know that a fence that will last in good condition for twenty years is cheaper than one that costs one half as much money and is useless in five years.

It is frequently asserted that wire for fencing is manufactured from the refuse of the furnaces and the junk piles, and that the metal used in forming the galvanized coating is largely adulterated with metals cheaper than zinc. The first contention shows ignorance of the fact that refuse metal of this kind could never be drawn to the form of wire, and that any manufacturer who followed such methods would speedily find his finished product on his own junk pile; and as to the second contention it may be said that, if it is true, no indication of the fact has been discovered during the course of the investigation.

The real cause of the trouble is a metallurgical problem and requires careful and impartial consideration. Evidence was easily obtained to show the truth of the original contention that the older iron wire is much more durable than modern steel wire. There is no question that the higher priced wire that is manufactured for telegraphic purposes is more durable than that used for fencing, and the reasons for this will be developed later.

A great number of samples of wire was sent to the Division of Tests, and a series of analyses was made to see whether chemical analysis would throw any light on the subject. It soon became noticeable that the majority of the old wires sent in which were in good condition were either free from manganese or containing only very small amounts — 0.2 per cent or under — of this metal. It is true that many of the good wires ran as high as 0.5 per cent, and even higher in manganese, but the fact was nevertheless noticeable that the bad wires, with very few ex-

ceptions, contained manganese, while the good wires were frequently, if not always, free from it.

The results of these preliminary experiments pointed undoubtedly to manganese as having something to do with the matter. The great difficulty was in explaining the exceptions. After a great deal of experimental work had been done in the chemical laboratory, however, one possible explanation appeared that might account for the facts obtained. Manganese dissolved in iron up to a certain percentage is known to increase the electric resistance of the metal. This means that iron wire containing manganese will resist the passage of electricity through it to a greater extent than a wire that contains little or no manganese. In case the manganese were not dissolved or mixed with perfect uniformity throughout, the iron electrical currents might be generated in the wire when wet which would lead to rapid corrosion. In order to get a practical opinion as to whether manganese was thought to have anything to do with the lasting quality of steel, the president and general manager of a company which is an enormous consumer of wire was appealed to, with the result that the following opinions which had been formed as the result of practical experience were received:

1. Bessemer or mild steel wire will rust or deteriorate much more rapidly than iron wire, in all probability three times as rapidly, although this is only an approximation.

2. The more manganese there is present, the shorter will be the life of the metal.

3. In soft steel the manganese will reduce the conductivity of the wire fully 50 per cent below the conductivity of wire containing only a trace of manganese.

It seemed from this that before the laboratory investigation instituted by the Department of Agriculture had been made, practical experience had indicated that manganese was at the bottom of the trouble. In further support of this conclusion, statements by James P. Roe, in a paper on the manufacture and characteristics of wrought (puddled) iron, which was presented before the Washington meeting of the American Institute of Mining Engineers in May, 1905, may be referred to; also a letter to the department from Dr. Henry M. Howe, an experienced metallurgist and the author of several well-known

books on iron and steel. With this evidence the following two points are accepted, at least for the time being:

1. That modern Bessemer and open-hearth steel rusts much more rapidly than iron wire. 2. That manganese, especially if it is unevenly distributed in the steel, is at least in part the cause of the trouble.

In order to pursue the inquiry further, it will be necessary to show just how the manganese can have the bad effect that it has. There is reason to believe that the cause of the rapid deterioration of steel fence wire has been traced to electrolysis induced by unequal distribution of manganese or other impurities. Wire that is hung in the field is in just the condition to suffer from electrolysis if the metal is not perfectly homogeneous in structure —-that is to say, if the manganese and other impurities are not perfectly distributed throughout the metal. All rain water contains small amounts of salts dissolved from the dust in the air, and is therefore a conductor of electricity. Differences of potential will occur in the wire, local circuits will be established through the wires or through the wires and ground, and currents will flow. This explanation is capable of accounting for the deep pitting observed in the corrosion of many wires, this pitting being characteristic of electrolytic action.

If manganese is unevenly distributed in the metal, why, it may be asked, have chemists generally failed to notice the fact in the course of large numbers of duplicate analyses that have so frequently been made? The answer to this question lies in the fact that such extremely small differences in the chemical composition as might easily escape detection in ordinary chemical analyses are still sufficiently large to account for slight differences of electrical potential. Metallurgists claim that even when a molten bath of metal is very evenly mixed in the beginning, the ingot made from this metal will show a certain amount of unevenness, owing to segregation, which takes place while the ingot is cooling.

Although it is probable that the effects of electrolysis in a fence wire are extremely small, it must be remembered that they are continually going on whenever the wire is wet. In almost all modern steel woven wire fences some wires will be found to far outlast others, independent of the original weight

of the galvanized covering which they carry. If in woven wire fence all the wires would last as well as the best ones do, there would have been no complaints and this investigation would never have become necessary. It is just this point of unevenness of lasting quality in wires from successive heats in the same mill, which have practically the same chemical composition, that is hard to explain by any theory but that of galvanic or electrolytic action. The manufacturers have believed that the whole trouble was in the unevenness in the weight of zinc covering that was put on the wire, but experiment and observation show that this is not so. Some wires will go to pieces before others, although there is no discernible difference either in the weight or quality of the zinc covering. In one fence, which has been under observation for four years, one wire was in perfect condition, although it carried a light covering of zinc, while the wire next to it was badly rusted from end to end.

Almost every one who has taken the pains carefully to inspect woven wire fence as it is exposed to the weather on the farm, has observed that some of the wires go to pieces much more rapidly than others. The bottom wires, lying close to the ground, which are kept wet in summer by the growth of weeds and grass, and in winter by melting snow, are naturally the ones which we should expect to rust most quickly. As a matter of fact, however, they almost never do so, but, on the contrary, are far more lasting than the wires farther removed from the ground. This observation has been substantiated by a large number of competent observers. Furthermore, wires that are stapled to living trees will almost invariably be preserved to some extent in the immediate neighborhood of the point of contact. One explanation that has been offered for these undoubted facts is that a certain protection from wind and weather is furnished by the growth about the wires, but this explanation is far from satisfactory. One would not seek to preserve iron from rust or zinc from corrosion by laying these metals away in wet snow or weeds. If, however, electrolysis takes place, and if the action can be diminished by keeping the wires electrically neutral through frequent connections to the earth or through frequent short circuits, we should then expect that wires which were kept along their whole length in constant contact with the earth would in the long run show greater lasting quality. Ex-

periments are at present being made to test the effect of earthing the fence by frequent connection to the ground.

A very much better covering, and perhaps a more durable wire, can be made by what is known as the double galvanized process. The double process does not, as its name implies, mean that more than one coating of zinc is put on, but only that about twice as much zinc by weight is carried by the wire. In the double process, the wire is drawn much more slowly through the zinc bath and does not pass through asbestos wipers, but is smoothed by passing through a shallow bed of slightly damp charcoal powder. Telegraph wire is usually treated by this method and is generally acknowledged to be more durable than fence wire, but it is worth noting at the same time that care is exercised in the manufacture of telegraph wire to keep the manganese low, because the presence of this element increases the electrical resistance of the wire. The difficulty experienced in rolling low manganese steel and the slow rate of speed at which the mill must be run to draw the wire through the zinc bath in the double process add materially to the cost of the product. It is a question that cannot be decided here whether or not high-grade fence wire is worthy of the same care and consideration that is given to wire which brings a higher price in the market and which is intended for other purposes. Within certain practical and possible limits, it is probably true that, other things being equal, the wire with the heavier zinc coating per unit of surface area will be the most resistant to weather conditions.

ABSTRACTS *

ELECTRIC Power from Blast-Furnace Gas. H. Freyn. Paper read before the Western Society of Engineers, Chicago, December 20, 1905. 8,000 w. — The author's calculation has been made assuming a new blast-furnace plant of two 400-ton blast furnaces, situated in the immediate vicinity of a large city and having the ordinary facilities for water supply and for handling the raw and finished material. Assuming both furnaces in good operation and assuming a coke consumption of 1,900 pounds per ton of pig iron, there will be required $800 \times 1,900 = 1,520,000$ pounds of coke per day. This quantity of coke produces approximately 110,000,000 cubic feet of gas in 24 hours, or, per ton of pig iron $110,000,000 \div 800 = 137,000$ cubic feet of gas. The losses on the top of the furnaces may amount to approximately 5 per cent, so that 130,000 cubic feet of gas per ton of pig iron produced in 24 hours could be obtained. The average heat value of this blast-furnace gas will be about 90 British thermal units per cubic foot. The total quantity of gas available for the various purposes in this blast-furnace plant amounts to $130,000 \times 800 = 104,000,000$ cubic feet of gas per 24 hours, or 4,350,000 cubic feet per hour, having a total heat value of 391,500,000 British thermal units. Modern, double acting, gas engines of large capacity, working on the four-cycle or Otto principle, built with the latest improvements and using high compression of mixture, consume less than 9,000 British thermal units per brake horse-power per hour at full load capacity. The total quantity of gas produced

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by two blast furnaces of 400 tons capacity each, when used in gas engines for generating power, would operate at least 391,500,000 ÷ 9,000 = 43,500 horse-power per hour. If, therefore, all the gas generated by a blast-furnace plant could be used for producing power, there would be available over 50 horse-power per ton of pig iron produced per 24 hours.

This quantity of 4,350,000 cubic feet of gas per hour will be divided for the various purposes of the blast-furnace plant as follows: One part of the gas is used for heating the hot blast stoves, another for operating gas blowing engines, and there is gas required for the auxiliary machinery, such as pumps, hoists, coke and ore handling machinery, power transmission, compressed air, pig-iron casting machinery, and for lighting the entire blast-furnace plant. Some of the gas is also necessary for operating gas engines serving the gas-cleaning plants and a certain percentage may be counted for losses in the piping, in the engines, the gas-cleaning plant, etc. It will be seen that the total quantity of gas necessary for the operation of the blast-furnace plant itself amounts to approximately 50 per cent of the total quantity generated, leaving a little less than 50 per cent available for useful work outside of the blast-furnace plant itself.

The author next considers the cost of an electric power station of 10,000 brake horse-power capacity and of operating the plant, and he concludes as follows:

" It will be seen that a power plant of about 10,500 brake horse-power capacity, complete in every detail and installed in connection with a blast-furnace plant, would be capable when running at full load capacity of producing 1 brake horse-power per year at the low cost of $17.88, no value being placed on the blast-furnace gas. The enormous saving, as compared with the production of power in a steam-engine plant, is still more striking when the cost generation of electric current is considered. According to the above tables 1 kilowatt hour at full load capacity of the plant could be produced at 2.5 mills, which is away below the best figure ever reached with a steam-engine power plant. Even under worse conditions — that is, when the power plant is running on an average of only 50 per cent of its total capacity — the cost of generation of 1 kilowatt hour is but 5.50 mills. It is evident that an eventual increase in the capacity of the power plant would still tend to reduce the cost of

the generation of power per unit, as certain expenditures for the power plant of 10,500 brake horse-power would remain unchanged for additional power units.

"Computations of this character are sometimes considered as being 'theoretical,' as they naturally can only be made by making certain assumptions. That such figures have some practical value, inasmuch as they permit the clear understanding of the results of practical experience, accounting for the make-up of these figures, will be appreciated by studying actual figures obtained in the works of the John Cockirell Company." **No. 457. D.**

The Technique of Microscopic Metallography (Sur la Technique de la Métallographie Microscopique).* H. Le Chatelier. " Revue de Métallurgie," July, 1905. 4,500 w., illustrated. — H. le Chatelier describes the improvements in the details of polishing, etching, etc., effected in his laboratory since the publication of his former article on the same subject.

Grinding. — A rapidly revolving emery wheel, against which the section is lightly pressed, gives the best results. For quenched steels which surface-heating might let down, a wheel flooded with water and revolving at slower speeds should be used. It has been stated that if the section does not become too hot to hold with the fingers, the temperature cannot rise sufficiently to have any effect on the metal. This is not the case, as the surface pressed against the emery wheel may be considerably hotter than the mass of the piece. To remove the modified skin which appears to be the unavoidable result of grinding on emery wheels, the section should be rubbed by hand on moderately coarse emery paper. Moistening emery paper with oil of turpentine hastens the operation. The edges of the section should be beveled to avoid tearing the polishing papers and cloths.

Fine Polishing. — The author insists on the importance of using powders of uniform dimension of grain. The time spent in their preparation is fully repaid by the increased rapidity of polishing. For iron and steel three powders are used, sieved emery, levigated emery (finer) and washed alumina. The author's methods for the preparation of these are given in detail. Fine flannel maintained in a state of tension on glass is used as

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* Abstracted in the " Journal of the Royal Microscopical Society."

supporting medium for the polishing powders. Filtered soap solution serves to fix the powder to the cloth. Surfaces thus prepared may be used for polishing dry or damp. To shorten the time occupied in polishing, revolving wooden disks, covered with fine cloth, or felt disks, may be used in the final stage when alumina is employed.

Methods of Etching. — A 5 per cent solution of picric acid in alcohol has come into general use. Two reagents recommended by Kourbatoff are: (1) Amyl alcohol containing 4 per cent nitric acid; (2) 4 per cent solution of nitric acid in ordinary alcohol 1 part, saturated solution of nitrophenol in ordinary alcohol 3 parts. Cementite is readily colored, other constituents not being affected, by a solution containing 25 per cent sodium hydrate and 2 per cent picric acid, at 100° C.

Microscope. — The author has abandoned the use of the mercury arc lamp, owing to the difficulties of manipulation and the long exposure required, though excellent photographs were obtained by its aid. A Nernst lamp with two thick filaments, so placed that their light is superposed on the illuminator of the microscope, gives good results; the source of light is sufficiently broad to eliminate the interference fringes which give trouble when an ordinary Nernst lamp with a thin filament is used. For steel sections exposures of two to five minutes are usually sufficient. Several modifications in the microscope and camera used by the author are described. It is more satisfactory to obtain high magnifications by employing objectives of higher power than by increasing the distance between plate and eye-piece. **No. 458. D.**

The Brittleness of Case Hardened Soft Steels (Sur la Fragilité des Aciers doux Cémentés).* J. Lecarme. "Revue de Métallurgie," July, 1905. 3,000 w. — To determine the cause of the brittleness resulting from the cementation of mild steel, J. Lecarme worked on steels of the following composition:

	1		2	
Carbon	0.100 per cent		0.090 per cent	
Manganese	0.300	,,	0.623	,,
Phosphorus	0.031	,,	0.065	,,
Silicon	0.750	,,	0.152	,,

* Abstracted in the "Journal of the Royal Microscopical Society," October, 1905.

Four groups, each made up of ten pieces of each steel, were packed (*a*) in neutral matter, (*b*), (*c*) and (*d*) in carburizing material of different degrees of activity, and heated at 1000° C., the different pieces in each group being maintained at this temperature for varying periods. The object of this series of experiments was to determine whether the brittleness is due to heating at a high temperature, or is influenced by the composition of the carburizing material. After treatment the pieces were submitted to mechanical tests and microscopically examined. The changes in microstructure are shown by photomicrographs. The author concludes that the thermal treatment necessarily accompanying cementation does not induce brittleness, this fragility being caused by some chemical change in the soft core taking place simultaneously with the superficial cementation. Widely differing degrees of brittleness result when steels obtained from different sources, though of similar chemical composition, are submitted to the same treatment. It is usually possible by suitable treatment to remove the brittleness resulting from cementation.

H. le Chatelier puts forward some criticisms of J. Lecarme's inferences, and remarks that the chief object of their publication is to induce other workers to investigate the subject more fully. The presence of nitrogen may influence the results. **No. 459. D.**

The Influence of Nitrogen on Iron and Steel (Influence de l'Azote sur le Fer et l'Acier).* Hjalmar Braune. "Revue de Métallurgie," July, 1905. 2,500 w. — The author points out that the abnormal brittleness frequently met with in iron and steel, especially in basic products, cannot be ascribed to the presence of large percentages of phosphorus, sulphur or other elements, the effect of which is well known. As the result of six years' work, the author states that this brittleness is caused by the presence of nitrogen absorbed by the metal in the processes of manufacture. The nitrogen exists as nitride of iron in solid solution in ferrite. To determine the effect of nitrogen on the quality of the metal, the author heated bars of high-grade iron and steel in ammonia gas at 800° C. for varying periods. Different proportions of nitrogen were absorbed; the bars were then annealed to bring about a regular diffusion of nitrogen through

* Abstracted in the "Journal of the Royal Society," October, 1905.

the metal. Curves are given showing the effect of increasing proportions of nitrogen on the mechanical properties of (1) soft iron containing 0.06 per cent carbon, (2) steel containing 1.15 per cent carbon. The effect is wholly injurious; 0.08 per cent, or more, nitrogen renders soft iron brittle; in the case of the high carbon steel the same effect results with only 0.03 per cent nitrogen. Photomicrographs are given showing the remarkable changes in structure brought about by increasing percentages of nitrogen.

In an editorial note appended to the above article, H. le Chatelier cites a number of facts — such as the well known difference in properties between acid and basic steel of the same composition — as to hitherto unexplained departures from established laws governing the relation between physical properties, chemical composition and thermal treatment of steel. These irregularities have been attributed to the presence of elements, such as hydrogen and oxygen, which are difficult to estimate. H. Braune's researches suggest that the explanation may be sought in the presence of nitrogen. H. le Chatelier gives some results he has obtained in endeavoring to establish a relation between brittleness of metals and their microstructure. He suggests that nitrogen, when present in moderate proportions, may have the effect of facilitating the development of brittleness under unsuitable thermal treatment, rather than that of rendering the metal hopelessly bad.

The method of estimating nitrogen in iron, together with further details, is given elsewhere by H. Braune. **No. 460. D.**

How Chrome Steel became an Industrial Product (Comment l'Acier Chrome est devenu un Product Industriel). A. Brustlein. "Revue de Métallurgie," July, 1905. 3,000 w. — The author reviews briefly the development of the applications of chrome steel. **No. 461. D.**

On the Choice of Cast Iron for Various Purposes (Die Auswahl des Giessereiroheisens für bestimmte Zwecke). O. Simmersbach. "Giesserei Ztg.," August 15, 1905. 3,000 w. **No. 462. B.**

The Conditions of Fan-Blower Design. Walter B. Snow. "Cassier's Magazine," January, 1906. 3,000 w., illustrated. **No. 463. B.**

METALLURGICAL NOTES AND COMMENTS

Léon Guillet   Léon Guillet (see frontispiece) was born at Saint-Nazaire, Loire Inférieure, France, in July, 1873. After studying at the Lycée Saint Louis, he entered the Ecole Centrale des Arts et Manufactures, from which he graduated as chemist in 1897. In 1899, he was intrusted with the installation of the now famous laboratories of De Dion-Bouton Company at Puteaux, near Paris, where he at once began his important and exhaustive investigations of special steels and alloys. He first gave his attention to those aluminum alloys which were then of so much interest to the manufacturers of automobiles. In 1892, he presented two theses to the Sorbonne, entitled " A Chemical Study of Aluminum Alloys," and " A Study of the Fusibility and Micrography of those Alloys," for which he was awarded the degree of docteur-ès-sciences. Mr. Guillet then undertook his well-known series of researches dealing with special steels, the results of which have been published in numerous papers, chiefly in the " Comptes Rendus " of the Académie des Sciences, in the " Revue de Métallurgie," and in the " Bulletin " of the Société d'Encouragement pour l'Industrie Nationale. Meantime Mr. Guillet published also some valuable papers dealing with the brittleness of steel, the cementation of steel, the quenching of bronzes, etc. He has also written several books on special steels and an important treatise on metallic alloys, the second volume of which is soon to be published. In 1901, he was awarded a prize by the Société des Ingénieurs Civils, and in 1904 his important contributions to the advancement of metallurgy were similarly recognized by the Société d'Encouragement. Mr. Guillet is also a Carnegie research scholar, and, at the last meeting of the Iron and Steel Institute, two papers of much importance were presented by him dealing with the special steels employed in the construction of automobiles in France, and with the use of vanadium in metallurgy.

While Mr. Guillet remains in charge of De Dion-Bouton laboratories, he is also consulting metallurgist for several impor-

tant industrial firms. Few metallurgists, and, indeed, few workers in any field of science, of Mr. Guillet's age, have conducted their work with greater industry, more logical treatment or greater experimental skill. He has contributed liberally and effectively to the progress of the metallurgy of special steels, and metallurgists and engineers will look to him for further advance in this interesting and important field.

Steel Castings and the Constitution of Steel.* --- Average steel castings, whether of surface blown Bessemer or open-hearth metal, usually contain about 0.35 per cent carbon, and in castings this element rarely exceeds 0.5 per cent. The higher the content of carbon the greater the tensile strength, within certain limits, but this increase in tenacity is always accompanied by a loss of ductility. As ductility usually figures on all specifications, tenacity alone is useless. Generally an elongation of from 15 to 20 per cent on 2 inches and a bending angle of 90 degrees is specified. A serviceable composition to meet the foregoing is as follows: Carbon, 0.3 per cent; manganese, 0.8 to 1.0 per cent; silicon, 0.2 per cent, with sulphur and phosphorus as much below 0.08 per cent as possible; from which it will be noted that with the exception of graphite, steel castings contain the

TABLE I

Carbon	Silicon	Manganese	Sulphur	Phos-phorus	Max. Stress Tons per sq. in.	Elongation Per cent on 2 in.
0.29	0.07	0.16	0.07	0.06	23.7	10.0
0.29	0.14	0.92	0.06	0.02	30.9	7.5
0.20	0.04	0.38	0.15	0.06	18.2	4.1

same elements, though in different proportion, met with in cast iron. Carbon gives rigidity, manganese and silicon both assist in the production of sound castings, whilst sulphur and phosphorus are decidedly harmful. A general limit of manganese is found in a content of 1 per cent, and silicon should not exceed 0.4 per cent, but these limits will naturally vary with the class of work. The figures in Table I illustrate the influence of manganese and sulphur.

* Abstracted from a paper by Percy Longmuir, " The Iron Trade Review," November 30, 1905.

These values are obtained from unannealed castings, and the first two show that with the same carbon but an increase in manganese of from 0.16 to 0.92 per cent, maximum stress is raised from 24 to 31 tons without a serious decrease in extensibility. The third example illustrates the influence of 0.15 per cent sulphur, and with this steel no form of heat treatment and no type of annealing would raise the extension above 10 per cent. Had the manganese been 1 per cent instead of 0.38 per cent, by suitable annealing an extension of 20 per cent could have been obtained. Evidently, then, manganese in steel, as in cast iron, neutralizes the harmful effect of sulphur. This is owing to the fact that manganese sulphide has a much higher freezing point than iron sulphide. Thus, on cooling, manganese sulphide solidifies early and its contraction is soon complete, further cooling and contraction tending to wedge the solidified globules of sulphide firmly in between the other constituents of the steel. Hence manganese sulphide occurs in isolated areas and owing to the pressure in a more or less globular form which does not destroy the continuity of the mass. On the other hand, iron sulphide solidifies comparatively late in the cooling process, hence as the mass is cooling this still liquid sulphide is rejected by the solidified portions of their boundaries. Further cooling results in the solidification of the iron sulphide and its contraction. Therefore, owing to late solidification and contraction, cohesion is seriously impaired. To this weak cohesion must also be added the fact that a brittle compound is distributed through the mass of the steel in a more or less connected form. No matter how thin this meshwork of iron sulphide may be, it most effectually destroys the continuity of the whole. As the strength of a chain is represented by that of the weakest link, so the strength of a steel containing iron sulphide is represented by the cohesion between the sulphide and the other constituents of the steel.

Turning to the effect of carbon, the following tests are taken from annealed castings and from bars cast on commercial castings:

Carbon Per cent	Max. Stress Tons Per sq. in.	Elongation Per cent on 2 in.	Reduction of Area. Per cent
0.08	20.0	40.0	60.0
0.28	28.0	33.5	45.6
0.51	35.4	22.5	27.3

These results were obtained from surface blown Bessemer steel, and are, for cast annealed metal, decidedly high, being almost equal to forged steel, except in the one property of resistance to shock.

Notwithstanding the present tendency to shorten annealing time, the writer's experience convinces him as to the value of a long anneal, and results such as the foregoing, which are regularly obtained, testify to the practical value of thorough annealing.

Annealing therefore determines the final properties of any steel castings, and to be successful it involves both time and temperature. The object is a twofold one, involving structural charges and the relieving of internal strains due to inequalities in the section of the casting. The latter is of much moment, and in the case of an intricate casting containing heavy and light masses of metal in juxtaposition, careful treatment is required. Unless this is given, an unannealed gray iron casting will under certain conditions prove of greater value under service conditions. A steel casting unrelieved of its contraction strains is a source of danger, and given the right conditions the castings will fly. Therefore the cooling down from the annealing temperature must be slow, and the slower the better the final result.

For castings containing from 0.3 to 0.5 per cent carbon, a suitable annealing temperature is found between 900° and 950° C., and a suitable time at this temperature is found in three full days (72 hours).

Steel Future of United States.* — J. Stephen Jeans, secretary of the British Iron Trade Association, in presenting a " World Survey of Iron and Steel " in a recent number of the " Manufacturers' Record," predicts a bright future for the industry in the United States.

" No one who has carefully studied the matter," he states, " can fail to see that the United States must contribute for the next half century, at any rate, the greater part of any future advance, alike in pig iron and in steel. No other country has the same supplies of cheap and rich raw material. No other country has its conditions of production in such good shape. No other country has such a colossal home demand. No other country can to the same extent enjoy the great benefits attendant upon

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production on a large scale.   No other country is better protected from outside competition.

" The average annual output of pig iron from the United States (exported) over the last four years has not exceeded 45,000 tons, and it is not likely to increase at present prices.   But this is not a criterion of what we may see in the future.   Although there are many countries in the world, less than 20 of them are pig-iron producers, and not more than four or five produce iron and steel for export.   The ' manifest destiny ' of the United States, with their vast resources, appears to me to be to produce more and more largely for export, and if it is found more profitable to export the finished forms of the metal rather than the cruder forms, so much the better for those engaged in the business.

Half the World's Supply

" Since 1902, the means of producing iron and steel have been greatly increased alike in all countries.   My friend, Mr. Swank, estimates the present capacity of the blast furnaces of the United States at over 30,000,000 tons a year.   This is probably equal to about one half the capacity of the whole world to-day.   Germany and Great Britain can under pressure produce about 22,000,000 tons and perhaps Russia, France and other countries could produce about 9,000,000 tons more, but this could only be done with some difficulty.   It is necessary to have about 10 per cent of furnace plants under repair or reconstruction at any one time, and Germany has been working close up to this limit for some years past. . . . Great Britain has a much larger proportion of her plants inoperative, and always has had, mainly because of the more ancient character of the conditions under which many of them have been worked.   It is not very probable that any large proportion of the plants now inactive in this country will be put in blast again. . . . No other European country is in a position to make large additions to its present output."

The Increase of Production

Mr. Jeans presents comparative tables of the ore output of the large producing countries for 1890 and 1904.   The United States almost doubled its output in that time; Great Britain remained exactly stationary; Germany doubled its output as did

France; Russia and Sweden made even larger gains though with relatively small tonnages at that, and Spain did little better than hold its own. During this period the increased use of leaner ores increased the average consumption per ton of iron from 2.03 to 2.2 tons. The same years showed corresponding increases in pig-iron output from 9,203,000 tons to 16,497,000 tons in the United States, from 4,651,000 tons to 10,058,000 tons in Germany and from 902,000 tons to 2,978,000 tons in Russia. Great Britain in the fifteen years gained only a little more than a half million tons, from 7,904,000 tons to 8,563,000 tons.

" Assuming that the quantity of pig iron now annually produced will reach 52,000,000 tons," continues Mr. Jeans, " it is probable that nearly 38,000,000 tons of that quantity, or 73 per cent of the whole, will be absorbed in the manufacture of steel. Hence it is clear that the future of the industry will depend on the demand for steel." The steel production for 1890 and 1904 in the leading countries was as follows: United States, 4,277,000 tons, 13,767,000 tons; Great Britain, 3,579,000 tons, 5,027,000 tons; Germany, 4,232,000 tons, 8,930,000 tons; total for all countries 11,985,000 tons, 35,815,000 tons.

Value of Unworked Ores

Concerning the scope of American iron ore deposits and their value, Mr. Jeans says: " It will not be overlooked in this connection that when the Steel Corporation was founded the value of the ores at its disposal was computed at $700,000,000, which worked out, I think, to about $1 per ton of the total quantity computed to be then available, and that, too, before any provision had been made for working or transportation. Probably this was not overstated. On the contrary, I should be surprised if the directors of the Steel Corporation, in view of the fuller knowledge that they now possess as to the limited volume of iron ores at command in relation to the increased and increasing output of iron, would not place the value of their unworked ores at more than they did in 1901."

The Steel Casting Industry Growing.* — The Bessemer pig-iron market lately has drawn attention to the growth of the steel casting industry. The producers of steel ingots are, generally

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* " The Iron Trade Review," January 18, 1906.

speaking, manufacturers of pig iron, and buy a comparatively small part of the pig iron they consume. The steel casting works, on the other hand, buy all the pig iron they use. They have been heavy purchasers of Bessemer pig iron in the past few weeks and have constituted an important factor in this market. As the production of basic open-hearth castings is relatively small, Bessemer is by far the chief grade of pig iron purchased for the manufacture of steel castings.

It being the present purpose merely to draw attention to the rate at which the production of steel castings is growing, it is unnecessary to refer to the advantages of the steel casting over the gray iron casting. Suffice it to remark that for many purposes, and particularly for railroad rolling stock, the steel casting has come into great favor. Something might also be said of the growth of the malleable casting industry, which uses a variety of Bessemer pig, but that also is foreign to the present purpose.

A recent summary, more or less complete and of course entirely trustworthy, presented by the American Iron and Steel Association, enumerates no less than 11 steel casting plants which have been completed since June 1, 1904, to which date the association's last directory was carried. A further list of erection in progress in December, 1905, enumerated no less than seven steel casting plants. In both cases these figures refer only to plants to use the pneumatic or open-hearth process. There has been new construction on a number of plants to use the crucible process, but on account of the relatively small tonnage of such plants it is not well to disturb the general figures by including them.

An interesting feature developed by the data referred to is that whereas the steel casting plants completed between June 1, 1904, and December 1, 1905, involved six converters of various patterns and nine open-hearth furnaces, the new construction now in progress involves eight converters and but one open-hearth furnace. This presentation is, of course, not conclusive as to the relative favor in which the two general processes now stand, but it is indicative. One reason for the diversion is that while the open-hearth furnace has for years been an accomplished fact, susceptible of comparatively little modification or improvement as regards the production of steel castings, the

Bessemer converter, or rather the general pneumatic process, has been much studied and a number of new types or variations have been brought forth. Another reason is that, as the steel casting encroaches further upon the field of the gray iron casting, the demand grows for a relatively cheaper product which, while not altogether as good as the finest casting possible with the open-hearth process, is yet greatly superior to the iron casting. The converter promises tonnage, and indeed its introduction has been somewhat delayed by the timidity of manufacturers who in some cases have shrunk from the tonnages they would have to market if they operated a converter with regularity. One of the claims put forth for a new converter is frequently the smallness of the tonnage on which it can be economically operated.

The effort to adapt the Bessemer or pneumatic process to the production of small tonnages, as for castings, is by no means a new one. It is rather that only in late years have the efforts been particularly successful. The old Clapp-Griffiths or stationary converter was once in considerable favor, but late in the eighties it began to retrograde, and is now scarcely heard of. About 1887 the Robert Bessemer process was introduced from France, and met with such a cordial reception that by November, 1889, there were seven Robert Bessemer plants completed in the United States, with a total of 11 converters, and one plant was being built, to contain three converters, making a total of eight plants with 14 converters. The American Iron and Steel Association's directory of June, 1904, showed but two Robert Bessemer plants, while it showed 17 other special Bessemer plants, with 25 converters, and since then there have been completed, or commenced, 11 plants, with 14 converters, of various types.

Statistics of steel casting production in 1905 are not yet available. The increase over any previous year will doubtless be found to have been very large, and production in the current year is destined to show a further large increase. Steel castings being used so largely for railroad work, the production naturally shows rather erratic variations. There was a slump of almost a fourth in production from 1903 to 1904. The statistics from 1898, the first year for which there are statistics, through 1904 show a rapid increase, except for the slump in 1904. They show a relatively greater increase in basic than in acid open-hearth

castings and in Bessemer than in open-hearth castings. From 1898 to 1901 basic castings aggregated less than a fourth the total of open-hearth castings; in 1903 and 1904 they constituted nearly a third. While the open-hearth casting production in 1904 dropped almost to the tonnage of 1901, the production by the Bessemer process, although relatively insignificant, increased from 1901 to 1904 by 137 per cent. A great increase from the 1904 production is to be expected for 1905 and 1906.

All the statistics which have been gathered on the production of direct steel castings in the United States are presented in the following table:

Production of Direct Steel Castings, Gross Tons

	Acid Bessemer	Basic Open-hearth	Acid Open-hearth	Crucible, etc.	Grand Total
1898	3,539	28,460	92,127	7,811	131,937
1899	3,939	38,689	130,040	7,444	181,112
1900	6,467	42,644	134,847	8,845	192,803
1901	6,764	94,941	206,681	9,184	317,570
1902	12,548	112,404	255,475	10,508	390,935
1903	18,099	134,879	165,469	11,818	430,265
1904	16,051	98,919	203,915	11,326	330 211

Effects of High Temperatures on Steels.* — As an interesting indication of the manner in which the methods of the physical laboratory are being applied to the solution of engineering problems, the work which is being done by Messrs. Hopkinson and Rogers in investigating the elastic properties of steel at high temperatures may be noted. In a recent communication to the Royal Society there is given an account of the researches which are being conducted in this direction, and although the work is by no means completed it is of immediate interest and value in its present form.

" Hitherto investigations into the elastic properties of metals have been confined to comparatively low temperatures. Gray, Dunlop and Blyth have measured the modulus of rigidity and Young's modulus for wires up to temperatures of 100° C., and found that both these quantities decrease as the temperature rises. Martens determined the influence of heat on the strength of iron up to temperatures of 600° C., but his experi-

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* " Engineering Magazine," November, 1905.

ments were the ordinary tensile tests carried to rupture; and though he also found a substantial diminution of Young's modulus with rise of temperature, he did not go into the point fully, being mainly concerned with breaking stress and elongation.

" In the experiments here described the elastic properties of steel and iron have been investigated at higher temperatures, ranging up to 800° C., and for stresses greatly below that required to rupture the material. It is found that as the temperature rises the stress-strain relations undergo a remarkable change, which may best be expressed by saying that what is variously called the time-effect or *elastische nachwirkung*, or creeping, increases greatly with the temperature. Steel at high temperatures behaves like india rubber or glass; if it is stressed for a time, and the stress removed, it does not at once recover; but after the immediate elastic recovery there is a slow contraction perceptible for many minutes. Such creeping can be detected at ordinary temperatures, but at a red heat it attains a different order of magnitude, becoming (in its total amount) a substantial fraction of the whole deformation."

The experiments of Messrs. Hopkinson and Rogers were conducted with the aid of an electric resistance furnace, the test specimen being placed in a vertical position in the middle of a resistance composed of three coils of nickel wire, this enabling satisfactory control of temperature to be maintained. The apparatus permitted the rapid application of loads up to $1\frac{1}{2}$ tons per square inch to be made, while an extensometer of Professor Ewing's pattern enabled changes in length to be measured up to the 50,000 part of an inch. The interior of the furnace was closed from the atmosphere by means of mercury seals, and the test piece was surrounded by an atmosphere of nitrogen, in order to prevent oxidation.

The trials, so far as made public, have been made upon two kinds of material, one being steel containing about 0.5 per cent of carbon, and the other being Low Moor iron. The results are shown in diagrams accompanying the original paper, from which some interesting deductions may be made.

The maximum temperature of the trials was 750° C., the bar being loaded up to about $1\frac{1}{4}$ tons per square inch for one minute and then unloaded for two minutes, this sequence being repeated a number of times, giving a curve showing the resulting

changes in length in terms of time. Even at this low stress the metal is shown to flow fairly rapidly, and the overstraining has a considerable hardening effect, this appearing in the diminishing amount of permanent set reproduced by the successive loadings. The hardening thus produced disappeared with rest, so that if the test bar is permitted to remain unstressed at a temperature of 750° C. for a few hours after having been hardened by successive loadings, it is found to be restored to its original soft state. This flow of the metal is very much slower with a slightly lower load.

" In respect of all the features hitherto mentioned the properties of the material differ only quantitatively from those of the cold bar. The results might, but for one remarkable difference, apply to a cold bar stressed to its yield-point. The difference lies in the behavior of the bar after the removal of the load. The cold bar does not contract appreciably; there is the instantaneous elastic contraction, then it stops. The hot bar, on the other hand, goes on shortening for two minutes or more after the load is off, as shown by the dotted line on the diagram, and the total amount of such shortening amounts to, roughly, one third of the instantaneous contraction, or one quarter of the total contraction, or one fifth of the average total extension after hardening has taken effect.

" The iron bar behaved in much the same way, but the metal flowed at a lower stress. There was considerable flow with a stress of but half a ton per square inch. The shortening after removal of load was also perceptible at that stress.

" At 600° C. both bars exhibited greater tenacity. A load of 1.6 tons per square inch applied to the steel bar for one minute produced an immediate extension of 3.8 extensometer divisions, followed by a slow drawing out which amounted in one minute to about 0.9 division. On removal of load there was an immediate shortening of 3.8 divisions, followed by a slow contraction amounting in two minutes to 0.7 division. The permanent extension produced was very small, if, indeed, there was any at all. The iron bar behaved in a similar way, but, as at 750° C., it yielded appreciably at a stress which was not sufficient to permanently deform the steel bar.

" The experiment on the steel bar at 600 degrees shows pretty conclusively that this slow recovery after release from

stress is not solely, or even mainly, dependent on overstrain. It seems to exist to a large amount with stresses which leave practically no permanent effect; the strain develops slowly under application of stress and disappears slowly after it is removed.

" This phenomenon is, of course, analogous to residual charge in glass and other dielectrics, — the stress corresponding to the electric force, and the strain to the electric displacement. Whether the law of linear superposition of the effects of stresses, closely followed in the electrical analogy, is true for hot steel or iron, is an interesting question which the apparatus was hardly sufficiently delicate to answer.

" The magnitude of this effect in steel may best be gauged by comparing it with other cases of the same kind, *e. g.*, with the slow recovery of a glass fiber after twisting; if such a fiber be twisted through a considerable angle for several hours, it will recover all but one fiftieth of the twist within two or three seconds of the removal of the stress. The remaining slow creep, amounting to one fiftieth of the whole deformation, corresponds to the slow return of the steel. In india rubber, under certain circumstances, 10 per cent of the strain disappears in time after the removal of the stress. But in steel at 600° C. the proportion is about 15 per cent.

" Another effect of ' creeping ' is to make the determination of Young's modulus a matter of some uncertainty. Thus the extension of the bar at 600° C. produced by a given load varies 15 per cent or more, according to the time of application of the load. When, however, the load is applied for a very short time, say of the order of one or two seconds, the strain produced seems to approach to a definite limiting value, which is the instantaneous extension or contraction of the bar observed in our experiments when the load is applied or removed. It seems reasonable to define Young's modulus for a metal in this state as the stress divided by this limiting instantaneous strain. It is then independent of the manner of loading, and is a definite physical constant; otherwise not. Owing to the effect of the ends, the reciprocal of the extension is not quite proportional to Young's modulus, their ratio being somewhat greater at high temperatures than at low, as already explained. With regard to this question it should be noted that the error in the determinations on the cold bar, and at 400° C., is probably not more than

about 2 per cent. At higher temperatures the error is greater, as, owing to the rapid drawing out of the bar, it was difficult to be sure of the instantaneous extension. It is, however, fairly certain that the ratio of Young's modulus in the cold bar and at 750° C. is not more than 10 per cent in error."

Iron v. Steel — Experience of the Pennsylvania Railroad.* — Speaking at the recent Washington meeting of the American Institute of Mining Engineers, Dr. C. B. Dudley gave a highly interesting description of the experience of the Pennsylvania Railroad Company as to the comparative values of iron and steel as constructive materials. He stated that there is now a tendency to return to the use of wrought iron in certain situations, whilst for the past twenty-two years the trend has been in the opposite direction, under the belief that the substitution of a homogeneous, well-made metal like steel must be an improvement on the use of iron — a non-homogeneous material, liable to suffer from flaws and bad welds. The experience of twenty years, however, had, he said, at length led to the conclusion that in certain constructions steel is proving less satisfactory than had been expected. This might be partly due, he continued, to the use of a steel ill-adapted for the work, or to faults in design or in workshop treatment; but he was also inclined to believe that there was a fourth cause. The trouble with steel had always appeared in articles subjected to bending. When subjected to direct tension and compression, on the other hand, it always showed itself much the better metal. Thus it had been found by experience on the Pennsylvania Railroad that the calculated stresses might at some points of a steel axle be 18,000 pounds to 20,000 pounds per square inch, whilst at others only 7,000 pounds to 12,000 pounds per square inch. Using steel of 65,000 pounds to 70,000 pounds tensile strength such an axle will sooner or later fail in service under these maximum stresses. The method of failure is peculiar. It generally begins at the fillet of the shoulder. The outer fibers give way first without showing any elongation, and their failure is followed by that of the fibers then exposed to the maximum stress, until finally the journal snaps off. If the steel is from 80,000 pounds to 85,000 pounds tensile strength, such failures will not occur. On the other hand wrought iron of

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* " American Machinist," January 18. 1906.

but 48,000 pounds to 52,000 pounds tensile stress will stand successfully the same fiber strains as require a steel of 80,000 pounds to 85,000 pounds tensile strength.

Iron and Steel in 1905.* — The year 1905 was not only the most productive and the most prosperous year in the history of the American iron trade but it was the most uniformly prosperous year. From January to December the demand for all leading forms of iron and steel and for the raw materials of their manufacture was continuous and insistent. There was no "dull season," no overloading of the markets, no slump in prices. Upon the other hand there was no great scarcity of iron and steel at any time, the markets in the main were well supplied, and consequently there were no "famine" prices. Few orders were sent abroad and our export trade was not neglected. Production was abnormally and phenomenally great, but, best of all, prices were wisely kept within reasonable bounds. We have heard of no complaints that prices were too high. We estimate the year's production in round figures at about 43,000,000 tons of iron ore, 23,000,000 tons of pig iron, and over 3,000,000 tons of steel rails. Even these extraordinary figures may be exceeded in 1906. The present outlook certainly justifies this opinion. The country is increasing its capacity to meet any possible demand that may exist in the near future for either pig iron or manufactured iron and steel. There were no strikes or lockouts in the iron trade in 1905 that are worthy of mention.

Standardized Drillings of Cast Iron. — Under date of December 26, 1905, the secretary of the American Foundrymen's Association has issued the following circular:

" We beg to announce the taking over by the government of our standardizing bureau, and that hereafter the standardized drillings of cast iron prepared and sold by our Association are to be obtained from the Bureau of Standards of the Department of Commerce and Labor.

" The American Foundrymen's Association has been highly honored by this recognition of its work, and the undoubted broadening out of the preparation of standard drillings now to

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* The " Bulletin " of the American Iron and Steel Association, January 15, 1906.

be expected will greatly enhance the value of standards for check determinations in the iron and steel industry.

" It is but fitting to recall the fact that to our president, Mr. Thomas D. West, belongs the credit of first calling attention to the advantages such a series of cast-iron borings, duly standardized by the ablest chemists of the country, would be to iron laboratories. To him for the successful building up of the enterprise, as well as to Professor Smith, of the Case School of Applied Science, for the details of manipulation, chemists all over the world are grateful, for the standards of the Association are accepted everywhere as arbiters in case of dispute.

" Director Stratton, of the Government Bureau of Standards, informs us that all orders for the drillings should be sent to the ' Bureau of Standards,' Washington, D. C. To avoid delay the remittance at the rate of $2.00 per sample of 150 grams, or three samples of 150 grams each for $5.00, should accompany the order, and this may be in form of a cheque or post-office order made payable to the Bureau of Standards."

The Andrew Carnegie Research Scholarship. — The following circular has, as is usual at this time of the year, been mailed to interested persons by the secretary of the Iron and Steel Institute:

" A Research Scholarship or Scholarships, of such value as may appear expedient to the Council of the Iron and Steel Institute from time to time, founded by Mr. Andrew Carnegie (past-president), who has presented to the Iron and Steel Institute eighty-nine one-thousand-dollar 5 per cent debenture bonds for the purpose, will be awarded annually, irrespective of sex or nationality, on the recommendation of the Council of the Institute. Candidates, who must be under thirty-five years of age, must apply on a special form, before the end of February, to the secretary of the Institute.

" The object of this scheme of scholarships is not to facilitate ordinary collegiate studies, but to enable students, who have passed through a college curriculum or have been trained in industrial establishments, to conduct researches in the metallurgy of iron and steel and allied subjects, with the view of aiding its advance or its application to industry. There is no restriction as to the place of research which may be selected, whether university, technical school, or works, provided it be properly equipped for the prosecution of metallurgical investigations.

" The appointment to a scholarship shall be for one year, but the Council may at their discretion renew the scholarship for a further period instead of proceeding to a new election. The results of the research shall be communicated to the Iron and Steel Institute in the form of a paper to be submitted to the annual general meeting of members, and if the Council consider the paper to be of sufficient merit, the Andrew Carnegie gold medal shall be awarded to its author. Should the paper in any year not be of sufficient merit, the medal will not be awarded in that year."

Cast Steel. *— The first steel castings made in this country of which anything is generally known, were crossing frogs made for the Philadelphia & Reading in July, 1867, by the William Butcher Steel Works, now the Midvale Steel Company. These castings were made from crucible steel of about the same hardness as tool steel, and while they had a smooth surface they were honeycombed throughout and far from perfect. Neither the Bessemer nor the open-hearth process of steel making was in successful use at that time. It was not until after the perfection of the open-hearth process, the Tropenas and other improved Bessemer processes, fifteen or twenty years later, that cast steel began to be used as a commercial material of construction, although the early experiments with crucible steel resulted in the discovery of several important principles of foundry practice, notably a suitable molding mixture and the use of manganese and silicon for producing sound castings. Within the last ten years the art of making steel castings of high tensile strength and ductility has reached the point where almost any shape which can be cast in gray or malleable iron can be made in cast steel. Large marine castings, stern posts, bed plates, hawse pipes and the like are now almost universally made of cast steel and smaller parts are made with an equally high percentage of perfect castings.

In car and locomotive work, cast steel is taking the place of cast, malleable and wrought iron, for many large and small parts. Couplers, draft sills, body bolsters, platform sills, truck bolsters, truck frames, journal boxes and even wheels are now being made of this comparatively new material. Locomotive

* " The Railroad Gazette," January 26, 1906.

frames, wheel centers, crossheads, axle boxes, rods and other parts are being made in large numbers, and have given good results in service. The greatest difficulty in making such castings of steel is the proper design of the piece, for with cast steel the shrinkage, tendency to honeycomb, and washing out of cores and small projections in the mold require a different foundry practice from that used in making gray iron castings. Sharp corners and thin ribs or webs must be avoided and proper provision made for risers and gates in the mold. Molten steel, if not hot enough, is sluggish, and if too hot is violently agitated by the gases formed in the mold. It has more of a tendency to wash off small projections in filling a mold unless carefully poured and in shrinking it contracts more than cast iron, and in a less uniform manner. Blowholes can be largely prevented by the mixture of manganese and silicon with the steel and perfect venting of the mold, but too high a proportion of these elements results in brittleness. Green sand molding is now used almost entirely, instead of the dry baked molds formerly employed, and with equally good, if not better, results. For duplicate work, such as coupler bodies and parts, molding machines are as well adapted for making steel castings as for gray and malleable iron castings.

The manufacture of couplers and bolsters from cast steel has reached a stage of development beyond which little more could be asked. Where weaknesses have developed, slight changes in the pattern or in the method of molding and location of gates, risers and sinking heads for feeding the casting in cooling have usually overcome the difficulty, and the standard makes of these parts of car equipment are turned out with a remarkably low percentage of defects. More complicated shapes, however, like locomotive frames, are often difficult to make perfectly, even though they have been designed as nearly as possible in accordance with the best practice in similar parts. The segregation and shrinkage sometimes cannot be determined until a few trials have been made with the patterns.

A committee of the Master Mechanics' Association in 1904 reported the preference of members in favor of cast-steel locomotive frames, based on the number of locomotives in use, as more than double the number in favor of hammered iron frames. Specifications for cast-steel frames were reported as follows:

" Acid open-hearth steel; 0.28 carbon, 0.05 phosphorus, 0.05 sulphur, 0.60 manganese; tensile strength not less than 55,000 pounds per square inch; elongation in 2 inches not less than 15 per cent; all frames to be annealed."

These specifications are well within the resources of the steel founder. A recent bridge specification requires acid open-hearth steel; sulphur, 0.05; phosphorus, 0.05; manganese, 0.80; silicon, 0.355; ultimate strength, 65,000 pounds; elongation, 20 per cent in 2 inches. The importance of careful foundry practice is emphasized in the committee's report, and also adequate annealing, which is an essential element in the process. Unannealed or poorly annealed steel castings are unreliable and weak.

The comparative strength and ductility of cast-steel is shown by the following table, compiled from tests made in 1891 by a committee of the Master Car Builders' Association.

Material	Ult. Strength	Comparative Strength c. i.=1	Elongation in 4 in. Per cent	Comparative Ductility Malleable Iron=1
Cast iron	20,000 lbs.	1.0	0.35	0.17
Malleable iron	32,000 lbs.	1.6	2.00	1.0
Wrought iron	50,000 lbs.	2.5	20.00	10 0
Cast steel	60,000 lbs.	3.0	10.00	5.0

The saving in weight for equal strength is about in proportion to the ultimate strength, and because of its high ductility cast steel can be used in places where cast iron cannot be used on account of the low resistance to shock, as in couplers and bolsters. Large, heavy, malleable castings cannot be made with strength in proportion to the weight, but with properly annealed steel castings the strength varies almost directly as the area of cross-section. The possibilities of this material have by no means been exhausted in car and locomotive work.

Early Use of Iron.* —Iron never found wide favor in ancient Egypt, but there are abundant evidences that it was used side by side with bronze for tools of various kinds. There is no reason to believe that it was ever commonly used for decorative purposes, either in architecture or otherwise. The

* From an article on Mining and the Use of Metals by the Ancient Egyptians, by Prof. R. D. George. " The Popular Science Monthly," December, 1906.

finding of iron bracelets proves that it was occasionally used for personal adornment. Even its use for tools seems to have been much more limited than that of bronze.

It has been suggested that the scarcity of iron objects may be accounted for, in part at least, by the readiness with which iron is destroyed by oxidation, especially in a soil so rich in niters as that of Egypt. It is also significant that the Asiatic neighbors of the Egyptians – –the Hebrews, the Canaanites, the Chaldeans, the Babylonians and other contemporaneous peoples — were familiar with the uses of iron.

Lepsius believes that this metal was used in Egypt as early as 3000 B.C., that it served primarily for hard instruments and was prepared in smelting furnaces. The Great Pyramid was built by Khufu (Cheops), of the fourth dynasty, and not later than 2800 B.C. Herodotus says that iron tools were used in the construction of the great pyramids, though others find reason to believe that the tools used were of tempered bronze. The question is of little importance in view of the fact that a band of iron was found in an inner joint of the Pyramid of Cheops, where the ancient architect placed it.

Thebes and Memphis are so ancient that history has preserved no record of their founding. Yet in the tombs of these long-decayed cities are found tools and other articles of iron, some of which may be seen among the treasures of the New York Historical Society. An ancient inscription at Karnak tells us that Thothmes I., who reigned in the eighteenth dynasty (probably 1500 B.C.), received from his chiefs and vassal kings "bars of wrought metal and vessels of copper and of bronze and of iron," and from near Memphis he received lead, iron, wine and wrought metal. Iron was so highly prized that it was considered a desirable article of plunder, and the soldiers of this same monarch, on their return from fighting Chadasha, brought "iron of the mountains, 40 cubes." An iron sickle was found beneath one of the sphynxes at Karnak, but it may have been placed there not more than 600 years B.C. When the great obelisk that now stands in Central Park, New York, was taken from its original position on the banks of the Nile, a piece of very pure iron was found beneath it. "Pieces of iron tools have been found at various places, bedded in masonry of very ancient date." (E.) In the twenty-fifth dynasty iron was used for the

door frames of the temple of Ptah. Very few of the iron relics found are well enough preserved to show the character of the workmanship, but they do show that the art of tempering iron was known at a very early date.

The known sources of Egyptian iron include the desert region of the south between the Nile and the Red Sea and the Sinai peninsula. At Hamami in the desert there are the workings of an ancient iron mine from which hematite was taken, but no evidences of smelting have been reported from this locality. The mines of the Sinai region must have been an important source of this metal as well as of copper. In 1873 ruins of extensive iron works of great antiquity, but of undoubted Egyptian origin, were discovered near the Wells of Moses, and it is possible than ancient Arabia learned the metallurgy of iron from the Egyptians. There is also reason to believe that iron was imported from Chaldea, Phœnicia, Babylonia and Assyria.

Of the metallurgical processes used in the treatment of iron ores little is known. Oxides or ochers of iron were used for the yellow, brown and red pigments so commonly used in Egyptian art. Some of the iron articles found are tools of various kinds, weapons, bracelets, keys, wire, door-frames, fish-hooks, etc.

Talbot Process Installations.* — Mention was made recently in these columns of the actions taken by the three companies in the Cleveland district, England, commonly known as the Furness companies, — the Weardale, Cargo Fleet and South Durham companies, — in acquiring a controlling interest in the Talbot Process Company of Great Britain. It is now estimated that the steel producing capacity employing the Talbot process amounts to nearly 1,000,000 tons a year in the United States and Great Britain. The installations now in operation or under construction are the following:

One 75-ton furnace, built in 1899 by the Pencoyd Iron Company, Pencoyd, Pa. Now in operation.

One 200-ton furnace, built in 1902 by Jones & Laughlin Steel Company, Pittsburg, Pa. Now in operation.

One 200-ton furnace, built in 1904 by Jones & Laughlin Steel Company, Pittsburg, Pa. Now in operation.

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* " Iron Age," January 18, 1906.

Three 200-ton furnaces, built in 1905, by Jones & Laughlin Steel Company, Pittsburg, Pa. Now in operation.

One 100-ton furnace, built in 1902 by Frodingham Iron Company, Frodingham, England. Now in operation.

One 130-ton furnace, built in 1905 by Frodingham Iron Company, Frodingham, England. Now in operation.

One 175-ton furnace, built in 1903 by Guest, Keen & Co., Cardiff, South Wales. Now in operation.

Two 175-ton furnaces, built in 1905 by the Cargo Fleet Iron Company, Limited, Middlesboro, England. Now in operation.

One 75-ton furnace under construction by the Cargo Fleet Iron Company, Limited, Middlesboro, England.

Two 175-ton furnaces under construction by the South Durham Steel & Iron Company, Limited, Middlesboro, England.

Two 175-ton furnaces under construction at the Malleable Works, Stockton-on-Tees, England.

Two 175-ton furnaces under construction by the Palmer Shipbuilding Company, Jarrow-on-Tyne, England.

Two 175-ton furnaces under construction at Longwy, France.

It is expected that the producing capacity under the Talbot process will be increased materially in 1906. In the United States the process is controlled by the Continuous Steel Process Company, represented by H. W. Lash of the Garrett-Cromwell Engineering Company, Cleveland.

Steel Rail Outlook.* — The " Wall Street Journal " publishes the following summary of the probable extent of the steel rail business in 1906. The rail mills of the country begin the year with close to 2,500,000 tons of business on their books, and the prospects are that the total production of the country in 1906 will be in the neighborhood of 3,300,000 tons, or about 300,000 tons in excess of the high record year of 1903, and 600,000 tons in excess of 1905. If the output is as large as expected, the tonnage will represent a gross business of $92,000,-000. There has been no extraordinary increase in steel rail production over the last seven years. As a matter of fact, rail production has not kept up in this respect with many other classes of finished steel. In 1901 the rail production of the country was 2,874,639 tons, and during the depression of 1904,

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* " Railroad Gazette," January 19, 1906.

2,284,000 tons were turned out. The production of steel rails over the last seven years, together with the price per ton and gross value, follows:

	Tons	Price per Ton	Gross Value
1906............	*3,300,000	$28.00	*$92,400,000
1905............	*2,700,000	28.00	*75,600,000
1904	2,284,711	28.00	63,971,908
1903	2,942,477	28.00	83,789,356
1902............	2,947,933	27.33	82,542,124
1901	2,874,639	27.33	78,463,788
1900............	2,385,682	22.29	76,933,671

The feeling in iron and steel circles is that, regardless of crop conditions, the rail mills will be kept active all through the current year. It is pointed out that the railroads will be forced to increase their equipment materially in order to conveniently handle the vast and ever-increasing amount of freight consigned to them. There are now 1,700,000 freight cars in use, but it is claimed that it would require many hundreds of thousands more to satisfactorily handle the freight. Nearly 1,000,000 freight cars have been manufactured in the last seven years, or at the rate of 130,700 a year. The output of rails generally moves in sympathy with the output of cars. The United States Steel Corporation now has a steel rail capacity of at least 2,300,-000 tons, but if the Youngstown mill continues to work on sheet and tin bars in preference to rails the corporation's production this year will not be as heavy as it otherwise would be. The rail production of the United States Steel Corporation over the last four years was as follows:

	Tons			Tons
1905..............	*1,700,000		1903..............	1,934,000
1904..............	1,240,000		1902..............	1,920,786

The exports of steel rails for the eleven months ended November 30, 1905, were as follows:

11 Mos.	Tons	Value	11 Mos.	Tons	Value
1905.......	273,306	$6,677,737	1904......	395,849	$10,182,402

As long as domestic consumption continues as large as at present, there is no likelihood of rail exports exceeding last year's shipments to any great extent.

*Estimated.

REVIEW OF THE IRON AND STEEL MARKET

It is now an open question whether the crest of the general wave of demand for iron and steel products has passed or the present is merely a lull before a period of renewed activity this spring. The mills and furnaces need not concern themselves particularly, since they are all sold up completely for several months ahead. The southern blast furnaces are sold up almost completely through the second quarter; in the north the prospective Bessemer output is sold nearly through the second quarter, while forge and foundry grades are sold into the second quarter. In rails more than two thirds of the possible output of the year is sold; in plates and shapes the mills have specifications for their entire output for four or five months; in merchant bars the specifications will run the mills for about three months, and in sheets and tin plates specifications will operate the mills through the first quarter.

Effective Monday, January 8, the following advances were made, in sheets and tin plates the advances being made by the leading interest and informally concurred in by the independents, in wire products the advance being made by a mutual understanding:

Black sheets, $2.00 per ton to 2.40 cents for No. 28 gauge.

Galvanized sheets, $2.00 per ton to 3.45 cents for No. 28 gauge.

Tin plates, 10 cents per box to $3.50 for 100-pound cokes.

Galvanized corrugated roofing, 10 cents to $3.00 per square for No. 28 gauge.

Wire products, $1.00 per ton to $1.85 for nails, 1.70 cents for plain wire and 2.30 cents for galvanized barb wire, jobbers' carloads.

On January 16 plates for Pacific Coast delivery were advanced $4.00 per ton to the regular Pittsburg basis of 1.60 cents, equal to 2.35 cents delivered.

Pig Iron. — Sales of steel making pig and pipe iron have been heavy; regular foundry grades have been comparatively

inactive. The United States Steel Corporation closed for a total of 115,000 tons of Bessemer pig, about 80,000 being for first quarter, at $17.25, valley, and the balance for second quarter, at $17.75, valley. Sales of various lots have been made to other consumers at intermediate prices. The Massilon independent pipe interest took 22,500 tons of northern and southern foundry and forge and the United States Cast-Iron Pipe and Foundry Company took a total of more than 40,000 tons, chiefly southern. The cast-iron pipe trade has been particularly active, some municipal contracts for pipe being let earlier than usual. Foundry iron has been relatively quiet, and the market on foundry irons is hardly as strong as it was, furnaces being more willing to shade prices for second than for first quarter. Prices are now as follows: F.o.b. valley furnace: Bessemer, $17.50 to $17.75; basic, $17.50; No. 2 foundry, $17.25 to $17.50; gray forge, $16.25 to $16.50. Delivered Pittsburg: Bessemer, $18.35 to $18.60; basic, $18.35; No. 2 foundry, $18.35 to $18.60; gray forge, $17.10 to $17.35. F.o.b. Birmingham: No. 2 foundry, $14.00 to $14.50; gray forge, $13.00 to $13.25. Delivered Chicago: northern No. 2 foundry, $19.25 to $19.50; malleable Bessemer, $19.25 to $19.50; Lake Superior charcoal, $20.50 to $21.50. Delivered Philadelphia: No. 2 X foundry, $18.50 to $18.75; standard gray forge, $17.00 to $17.50. Freight: valleys to Pittsburg, 85 cents; to Chicago, $2.30. Birmingham to Pittsburg, $4.35; to Cincinnati, $2.75; to Chicago, $3.65; to Philadelphia by rail, $4.00. These rates from Birmingham will be advanced 25 cents on March 1, making the rate to Ohio River points $3.00 and advancing the rate to other points by the same amount. The water rate to Philadelphia remains at $3.50.

Ferro-Manganese. — The famine in prompt ferro-manganese continues, and as high as $175 has been paid for small lots for guaranteed spot shipment. Some lower grade ferro has been coming in, and has sold at $135 for 60 per cent, standard ferro containing 80 per cent of metallic manganese. Future delivery is also higher, and contracts for delivery beginning July 1 can hardly be made at as low as $85, which was rather freely quoted the middle of January.

Steel. — The supply of billets and sheet bars has not improved materially, mills still being decidedly behind on their contracts. It is rumored that some sales have been made by

producers who have not lately been in the market. Open-
hearth billets have again become very scarce, and cannot be
quoted. Forging billets are also harder to buy, and would
bring $30 or higher, Pittsburg. Ordinary soft Bessemer billets
can be quoted nominally at $26, Pittsburg, and sheet bars, long
lengths, at $27. Wire rods are $32.50 to $33.00, Pittsburg.

Rails. — While the heavy buying of rails was done some time
ago, there has since been a good run of business, the mills selling
each week an average of more than their current output. It
can safely be said that more than two thirds of the year's rail
output has now been sold. The price remains at $28, mill, for
standard sections, 50 pounds and heavier. Early in January
another advance in light rails was made, making the total
advance $3.00 per ton since August, prices being now as follows,
f.o.b. mill: sections 25 to 45 pounds, $28; 20 pounds, $29; 16
pounds, $30.

Shapes. — A very satisfactory run of business is being
booked by the fabricating interests, which immediately cover
by specifications to the structural mills on their contracts. The
mills are filled with specifications for fully four months ahead,
and on some work for six or seven months. Regular mill prices
remain at 1.70 cents for beams and channels, 15-inch and under,
zees and angles, 1.75 cents for tees, and 1.80 cents for beams and
channels over 15-inch, all f.o.b. Pittsburg plus full rail freight to
destination, except that shapes for the three Pacific Coast states
remain based on 1.40 cents, Pittsburg.

Plates. — Very little new business is being booked for steel
car purposes, the steel car makers being filled for this year.
The railroads, however, are showing signs of coming into the
market for next year's deliveries. A satisfactory run of business
continues in plates for ship and miscellaneous purposes. Plates
for the Pacific Coast states were on January 16 advanced to the
Pittsburg basis of 1.60 cents, for tank quality, so that the Pitts-
burg basis now controls the whole country, the differential of
20 cents a hundred for the Pacific Coast being removed.

Merchant Bars. — The iron bar market is slightly easier, it
being possible to do 1.80 cents, Chicago, against 1.85 to 1.90
cents at the time of last report, while the market at Pittsburg
and in the east is also a trifle easier. Some eastern mills are
willing to shade the regular price of 1.83½ cents, Philadelphia, by

$1 to $2 a ton. At Pittsburg the leading interest continues to quote on the basis of 2 cents, Youngstown, but some bars can be had at about 1.90 cents, Pittsburg. Steel bars are very firm and unchanged at 1.50 cents, Pittsburg, with new business relatively light but specifications heavy.

Sheets. — With the advances of $2.00 a ton in black and galvanized sheets, 10 cents a box on tin plates and 10 cents a square on galvanized corrugated roofing, prices are now as follows: No. 28 gauge, black, 2.40 cents; galvanized, 3.45 cents; painted corrugated roofing (unchanged), $1.65 per square for No. 28 gauge, 2½-inch corrugations; 100-pound coke tin plates, $3.50, all f.o.b. Pittsburg in carload and larger lots. Deliveries are being made on old contracts, comparatively little new business being placed. The mills are well filled up for the current quarter, with considerable business booked for second quarter.

Scrap. — The market has become very soft, largely on account of the open winter, which has upset all calculations. Heavy melting scrap has been sold at $17.00 and $17.25, and it is possible that $16.75 could be done. Car wheels are strong at $19.00, the car-wheel foundries being very busy, while old iron car axles are also strong, on account of the high prices of muck bar and billets, and bring about $29. Other grades are weak at the following nominal prices: cast-iron borings, $10.50; sheet scrap, $15.25; wrought-iron turnings, $14.00. Nearly all the mills in the east are embargoed.

Connellsville Coke. — Coke has declined further, and $2.50 can be shaded slightly on standard Connellsville furnace coke for prompt shipment, while $3.40 or less has been done on prompt 72-hour foundry coke. There is no interest in contract coke at present. Possibly the market is weak only temporarily, as it has been made largely by the forcing on to the market of coke which was loaded and has to be disposed of to avoid demurrage charges.

STATISTICS

Iron Ore Receipts at Lake Erie Ports.* — The following tables, compiled by the " Marine Review," show the receipts of Lake Superior iron ore at Lake Erie ports and the quantities left on dock on December 1 during the last three years.

IRON ORE RECEIPTS AT LAKE ERIE PORTS — GROSS TONS

Ports	1903	1904	1905
Toledo	652,305	508,793	1,006,855
Sandusky	130,532	48,356	51,202
Huron	486,106	231,364	825,278
Lorain	990,490	972,931	1,605,823
Cleveland	4,434,160	3,572,228	5,854,745
Fairport	1,434,342	1,157,858	2,008,621
Ashtabula	4,242,160	3,639,250	6,373,779
Conneaut	3,903,937	4,083,655	5,327,552
Erie	1,257,798	1,284,778	2,112,476
Buffalo } Tonawanda }	2,149,901	2,433,601	3,312,725
Total	19,681,731	17,932,814	28,479,056

IRON ORE ON LAKE ERIE DOCKS, DEC. 1 — GROSS TONS

Ports	1903	1904	1905
Toledo	106,710	318,573	368,024
Sandusky	95,275	75,134	52,977
Huron	253,249	182,495	208,023
Lorain	288,581	299,504	271,695
Cleveland	1,337,750	1,237,033	1,330,619
Fairport	845,946	660,420	759,961
Ashtabula	1,911,911	1,403,575	1,589,951
Conneaut	591,364	684,487	976,976
Erie	657,409	583,439	564,961
Buffalo	282,890	318,739	315,780
Total	6,371,085	5,763,399	6,438,967

The difference between the output of 33,476,904 tons which was shipped from the mines by water during 1905 and the

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* " Bulletin," American Iron and Steel Association, January 20, 1906.

receipts of 28,479,056 tons at Lake Erie ports represents ore that went to places other than Lake Erie ports, such as furnaces at Detroit and South Chicago.

Furnace Exhibits. — From some statistics published in the " Bulletin " of the American Iron and Steel Association (December 20, 1905), it is estimated that 29 long idle and entirely new stacks, with a total annual capacity of 2,253,500 tons, are likely to be blown in between January 1, 1906, and the fall of that year, and that of this total 19 stacks, with an annual capacity of 1,995,000 tons, will use coke for fuel; 2 stacks, with an annual capacity of 110,000 tons, will use anthracite coal and coke mixed; one stack, with an annual capacity of 36,000 tons, will use anthracite coal alone; and 7 stacks, with an annual capacity of 112,500 tons, will use charcoal.

RECENT PUBLICATIONS

Practical Pattern-Making, by F. W. Barrows. 5 × 7-in. pages; 141 illustrations. The Norman W. Henley Publishing Company. New York. 1906. Price, $2.00. — The art of pattern making is described in this book in a practical manner and quite exhaustively, including work both in wood and metal. The first part is Introductory, while the five other parts are devoted to the following subjects: Materials and Tools, Some Example of Wood Patterns, Metal Patterns, Pattern Shop Mathematics and Cost, Care and Inventory. The author is a pattern maker of thirty years' experience.

Le Vanadium, by P. Nicolardot. 177 4 × 7½-in. pages; paper covers. Gauthier Villars. Paris. Price, $0.75. — That a book should have been written describing the occurrence, production, properties and uses of a metal which until very recently was on the list of the " rare " elements is sufficient evidence of its growing industrial importance. The author first relates interestingly the discovery of the metal and then passes to a description of its occurrence, its minerals, its production and its uses with special reference to the recent production of vanadium steels. Steel metallurgists are taking a growing interest in the manufacture of these steels, and are carefully studying the results obtained by various investigators. This little book, therefore, cannot fail to prove of interest to many.

Engineering Chemistry, by Thomas B. Stillman. Third edition. 597 6 × 9-in. pages; illustrated. Chemical Publishing Company. Easton, Pa. 1905. Price, $4.50. — This is the third edition of a widely and favorably known book. In the present edition the necessary revisions have been made in order to describe the most modern methods of testing the various products of chemical technology and the materials of construction. Much additional matter has been incorporated,

especially relating to asphalts, lubricating oils, Portland cement and the technology of the products of the blast furnace.

Select Methods of Quantitative Analysis, by Byron W. Cheever and Frank Clemes Smith. Fourth edition, revised and enlarged. Parts I and II. 273 $5\frac{1}{2}$ × 9-in. pages. George Wahr. Ann Arbor, Mich. 1905. Price, $2.00. — The first part of this book, which occupies sixty pages, consists of Laboratory Notes for a Beginners' Course in Quantitative Analysis. It considers the subjects of Gravimetric and Volumetric Analysis, for beginners, by means of the analyses of a set of substances, properly numbered and arranged in what seems to be a desirable order for study, in each case giving the methods to be followed in each analysis; it also gives the methods to be used in calculating and preparing standard solutions for volumetric work, generally following the course offered by Professor Cheever to his students.

The second part, which was first published by Professor Cheever in a separate volume, contains a number of methods in inorganic quantitative analysis, which he had carefully worked out and which were ratable among the most improved methods in use at that time. In the three editions which have been published by Professor Smith since the regretted death of Professor Cheever, the progress of the science of chemistry has necessitated an almost entire change of this part of the work, in order that the book may contain nothing but the most modern practice at the time of issue. This has resulted in the elimination of nearly all of the matter originally contained in the book. The book has a very good index of 25 pages.

Second Year Chemistry, by Edward Hart, Ph.D., professor of chemistry in Lafayette College, Easton, Pa. 165 5 × $6\frac{1}{2}$-in. pages; illustrated. Chemical Publishing Company. Easton, Pa. 1905. Price, $1.25. — In this text-book which is adapted to second-year students the following subjects are concisely and methodically described: Molecules and Atoms, Properties of Gases, Gas Analysis, Dissociation, The Chemical Balance, Volumetric Analysis, Gravimetric Analysis, Qualitative Analysis, The Preparation and Use of Reagents, Filtration and the Treatment of Precipitates, Scheme for the Examination of

Metals, Non-Metals, Chemical Arithmetic and Quantitative Analysis.

The Production of Aluminum and Its Industrial Use, by Adolphe Minet; translated by Leonard Waldo.   266 5 × 7½-in. pages; illustrated.   John Wiley & Sons.   New York.   1905. Price, $2.50. — The following short preface by the author indicates the nature of this book: " The present work comprises a principal part, which is a literal translation of the German edition, " Die Gewinnung des Aluminiums und dessen Bedeutung für Handel und Industrie," published in 1902, and an appendix including two wholly new chapters: the first, by the author, is devoted to a supplementary consideration of those parts of the German edition which have been made the subject of criticism; in the second chapter, Dr. Leonard Waldo describes the developments in the aluminum industry of recent years, more especially in the United States — a matter which the limited scope of the first book had compelled me, greatly to my regret, to overlook."

The book is divided into two parts, the first one being devoted to a description of the processes for the production of aluminum, and the second to the properties of aluminum and its alloys, methods of working and uses.   There is also an appendix in which Mr. Minet answers some criticisms which appeared shortly after the publication of the German edition, chiefly in the " Zeitschrift für Elektrochemie," while the translator devotes some twelve additional pages to Aluminum in the United States, chiefly of an historical character.

The treatment of the subject is in every way satisfactory, and this little book should be warmly welcome by all those interested in the aluminum industry or in the use of aluminum and its alloys.   The book is finely printed and illustrated, while the binding is substantial and attractive, suggesting by its color the pleasing luster of the metal described.

Quantitative Metallurgical Analysis, by Charles Frederick Sidener.   58 5½ × 8-in. pages; illustrated.   H. W. Wilson Company.   Minneapolis, Minn.   1904.   Price, $1.00. — This little book consists of a collection of selected methods for the chemical analysis of ores, slags, pig iron and steel.   The meth-

ods described are generally standard methods and they have apparently been selected with intelligent care.

Minerals in Rock Sections, by Lea McIlvaine Luquer, adjunct professor of mineralogy, Columbia University, New York City. Revised edition. 141 6 × 9-in. pages; illustrated. D. Van Nostrand Company. 1905. Price, $1.50. — This is a new and revised edition of Professor Luquer's book, which was first published in 1898. The methods employed for preparing sections of rock for microscopical examination are described and the microscopic and optical characters of minerals are systematically recorded. An optical scheme is appended with the minerals grouped according to their common optical characteristics. The subject is treated concisely but clearly, only those facts which are absolutely necessary for the proper identification of the common minerals in rock sections being considered.

Electrolytic Dissociation Theory, by Henry P. Talbot and A. A. Blanchard. 84 6 × 9-in. pages; illustrated. The Macmillan Company. New York. Price, $1.25. — The authors write that in this little treatise they have sought to bring together, in small compass, material relating to the Electrolytic Dissociation Theory which is now somewhat widely distributed throughout many of our excellent text-books. The method of presentation is that which they have found serviceable in enabling their students to comprehend the main facts which are to-day generally accepted as supporting the theory, and to understand its application to important types of chemical change. Fifteen experiments are appended to the book.

The Science Year Book for 1906. 360 5½ × 9-in. pages; illustrated. Edited by Major B. F. S. Baden Powell. King, Sell & Olding, Ltd. London. Price, 5s. — This annual, which was published for the first time last year, includes a large amount of information presented in a handy form and relating chiefly to astronomy and meteorology. It also contains, however, information of a more general interest, such as a list of English and American scientific periodicals with name and address of editor, subscription price, etc.; a list of public institutions; a

list of English and American scientific and learned societies; biographies of many men of science (English only); a list of prizes and awards for scientific research; a list of books and important papers published during the year; a glossary of recently introduced scientific terms, etc.

Transactions of the American Electrochemical Society. Vol. VII. 345 $5\frac{1}{2}$ × 9-in. pages; illustrated. Published by the Society. Philadelphia, Pa. 1905. Price, $3.00. —The present volume contains the proceedings of the seventh meeting of the association, held in Boston and Cambridge, Mass., in April, 1905. It includes twenty-eight papers, dealing with many different phases of electrochemical phenomena and related subjects. A portrait of Prof. W. D. Bancroft is reproduced as a frontispiece.

BOOKS RECEIVED

The following books have been received and will be reviewed in an early issue of the *Iron and Steel Magazine.*

American Society for Testing Materials. Vol. V. Edited by the Secretary. 565 6 + 9-in. pages; illustrated. Published by the Society. Philadelphia, Pa. 1905.

Métallurgie Générale, Procédés de Chauffage, by U. Le Verrier, Chief Engineer of Mines, Professor at the Conservatoire des Arts et Métiers. 366 $6\frac{1}{2}$ + 10-in. pages; illustrated; paper covers. Gauthier-Villars. Paris. Price, 12 francs.

Conversations on Chemistry, Part II, by W. Ostwald, Professor of Chemistry in the University of Leipzig. 373 5 + $7\frac{1}{2}$-in. pages; illustrated. John Wiley & Sons. New York. 1906. Price, $2.00.

A Treatise on Chemistry, by Sir H. E. Roscoe, F.R.S., and C. Schorlemmer, F.R.S. Vol. I. The Non-Metallic Elements. 931 $5\frac{1}{2}$ + $8\frac{1}{2}$-in. pages; illustrated. Macmillan & Co. London. 1905. Price, $5.00.

A Manual of Assaying, by Alfred Stanley Miller, Professor of Mining and Metallurgy, University of Idaho. Third edition; revised and enlarged. John Wiley & Sons. New York. 1906. Price, $1.00.

Esperanto. The Student's Complete Text-Book. Compiled by J. C. O'Connor, B.A. 175 $4\frac{1}{2}$ + 4-in. pages. Fleming H. Revell Company. New York. Price, 50 cents.

Encyclopedia Americana. Editor-in-Chief: Frederick Converse Beach, editor "Scientific American." Managing Editor: George Edwin Rines. Sixteen illustrated volumes. Scientific American Compiling Department. New York. Price, half morocco, $96.00.

Eminent Engineers, by Dwight Goddard. 280 $5\frac{1}{2}$ + $7\frac{1}{2}$-in. pages; illustrated. The Derry-Collard Company. New York. 1906. Price, $1.00.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

807,026. PROCESS OF CONVERTING CAST IRON INTO IRON OR STEEL. — Paul L. T. Heroult, La Praz, France, assignor to Société Electro Métallurgique Francaise, Froges, Isere, France.

807,028. PROCESS OF OBTAINING SOUND INGOTS. — Paul L. T. Heroult, La Praz, France, assignor to Société Electro Métallurgique Francaise, Froges, Isere, France.

807,071. GAS-PRODUCER. — Bruno Graupe. Cologne-Deutz, Germany.

807,594. GAS-PRODUCER. — William H. Bradley, Bellevue, Pa., assignor of one fourth to Alexander Gilliland and one fourth to William C. Bradley, Bellevue, Pa., and one eighth to Sara L. Bradley and one eighth to Mrs. M. E. Webster, St. Louis, Mo.

807,850. APPARATUS FOR MARKING METAL BLOOMS, BILLETS OR SLABS. — George E. McCaffrey, Steubenville, Ohio.

808,103. ART OF GALVANIZING METALS. — Guy L. Meaker, Evanston, Ill., assignor to the American Steel and Wire Company of New Jersey.

808,244. GAS-PRODUCER. — Ernst Keerting, Hanover, Germany.

809,021. PROCESS OF PREVENTING THE FORMATION OF CLINKER IN GAS-PRODUCERS. — James E. Sheaffer, Burnham, Pa., assignor to one half to Orville C. Skinner, Burnham, Pa.

809,023. GAS-PRODUCER. — Orville C. Skinner and James E. Sheaffer, Burnham, Pa.

809,067. SIEMENS REGENERATIVE FURNACE. — Adelbert Kurzwernhart, Zuckmantel, near Teplitz, Austria-Hungary.

809,291. ART OF MANUFACTURING IRON OR STEEL. — Emil Fleischer, Dresden-Strehlen, Germany, assignor to Jacob Eduard Goldsmith, Frankfort-on-the-Main, Germany Filed July 26, 1904.

809,295. GAS-PRODUCER. — Jerome R. George, Worcester, Mass., assignor to Morgan Construction Company, Worcester, Mass., a corporation of Massachusetts. Filed July 10, 1903.

809,754. CHARGING APPARATUS FOR BLAST-FURNACES. — Gibbon C. Shackleford, Allegheny, Pa. Filed August 26, 1903.

GREAT BRITAIN

21,755 of 1904. BRIQUETTE MAKING. — L. Marton, Budapest, Hungary. The use of starch and gluten for binding briquettes of coal or ore.

5,367 of 1905. STEEL FURNACE. — J. J. Hudson, Philadelphia. Improved furnace for refining iron or steel by means of charcoal, and subsequently decarburizing.

3,225 of 1905. DE-COPPERING IRON AND STEEL. — W. R. Hodgkinson, London. For removing copper and nickel from iron and steel surfaces, the use of a solution of an amide of an organic acid mixed with cuprous chloride.

15,296 of 1905. TILTING FURNACE. — T. H. Treat, Pittsburg. Improved framework for supporting tilting open-hearth steel furnaces.
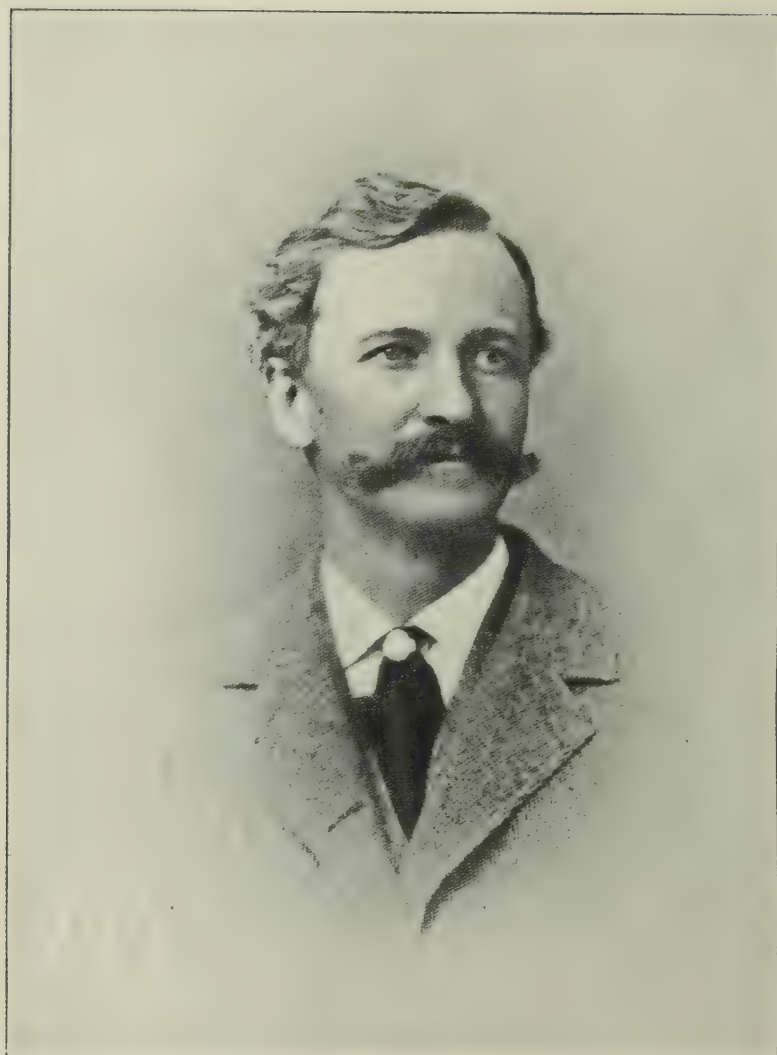
ALEXANDER LYMAN HOLLEY

SEE PAGE 251

IRON-CARBON ALLOYS WITH HIGH PERCENTAGES OF CARBON *

By F. WÜST

THE chemical analysis of metals and alloys and the testing of their mechanical properties has only recently become effective for the metallurgist through the explanations of the nature of alloys. Through Prof. A. Martens of Berlin, the microscope as an aid in the investigation of metals and metal solutions has come into vogue; and to the application of this method of investigation in connection with the study of the processes of cooling and solidification is due the knowledge of many new facts concerning the nature of alloys.

A peculiar circumstance in reference to the investigation of the iron-carbon alloys is that the alloys of iron with a low per cent of carbon, that is iron and steel, have been examined much more thoroughly and completely than those with a higher per cent of carbon, which we term white and gray cast iron. Hence it is not surprising that our knowledge of the mechanism of the solidification of these alloys up to 2 per cent carbon and of their thermal treatment is quite extensive, and that the theories concerning these processes conform to the observed facts. It is different in the matter of the alloys with a higher per cent of carbon. Here the experimentally determined facts are not very numerous and in part contradictory, so that in this case the proposed theory of the processes of cooling and solidification cannot claim universal value. This theory will be shortly described.

* " Métallurgie," January 8, 1906. Translated for the *Iron and Steel Magazine.*

The element iron exists in three modifications as α-, β- and γ-iron which merge into each other at the temperatures 780° C. and 900° C. They differ from each other in their capacity for dissolving carbon; γ-iron can hold, according to the temperature, from 0.9 to 2 per cent carbon in solution, β-iron possesses a more limited capacity and α-iron none at all as a solvent for carbon. Moreover, iron and carbon may unite to form the carbide Fe_3C and the latter may be dissolved in iron; whether the carbon as such is present in the solutions or combined as carbide could not hitherto be determined. Many circumstances,
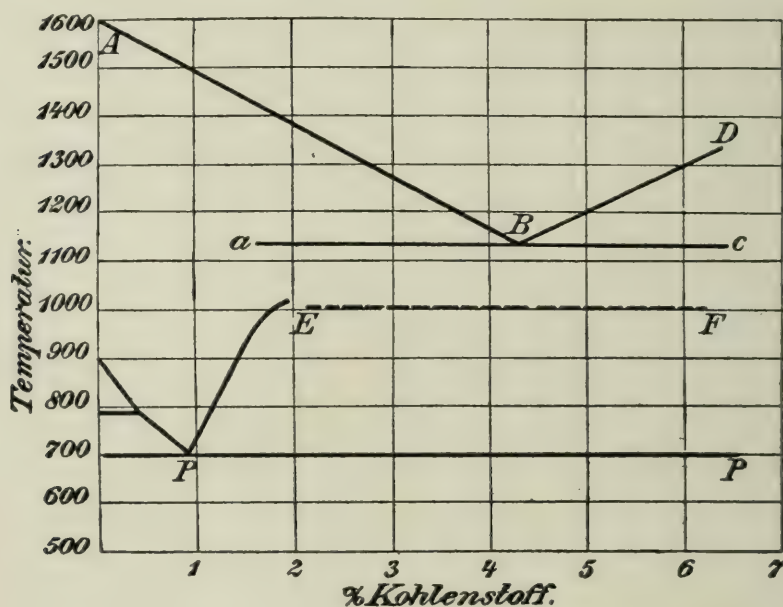
Fig. 1.

however, indicate that at least at temperatures below 1000° C. the carbon is in solution as carbide. The study of the behavior of these alloys during cooling and heating, whereby the formation or the disappearance of some constituents is indicated by the evolution or absorption of heat, result in the diagram shown in Fig. 1, according to Roberts-Austen, in which the abscissas give the per cent in carbon and the ordinates the temperatures.

The lines are produced by the union of all those points at which during cooling a momentary stop in the decrease of temperature takes place. According to the explanations of Prof.

B. Roozeboom,* the cooling of an iron with about 3 per cent carbon proceeds as follows: At 1250° C. a solid solution of iron with 1.5 per cent carbon begins to separate while the mother liquor increases its amount of carbon to 4.3 per cent and at the same time the temperature sinks to 1130° C. At this temperature the composition of the mother liquor solid solution †— graphite — is reached and the temperature remains at this point until the whole mass is solidified. If it were possible to keep this condition at ordinary temperature an intimate mixture of mixed crystals with graphite must appear. With further cooling at a fixed temperature (1000° C.) the carbide is supposed to form, according to the equation, solid solution + graphite = carbide, so that below this temperature, provided the above reaction proceeds quantitatively, we shall have solid solution + carbide. With decreasing temperature the capacity of the solid solution for carbon decreases more and more, so that more carbide is separated out until the solid solution has attained 0.9 per cent carbon while the temperature has fallen to 700° C. Analogous to the fluid mother liquor solid solution — graphite — at 1130° C., a mother metal of constant composition (0.9 per cent carbon) remains behind at 700° C., which at this temperature divides into its components: iron and carbide. Consequently we have finally only two constituents, carbide and iron, or, according to their metallographic terms, cementite and ferrite. With a per cent of carbon above 4.3 per cent, the processes would take place in a similar manner except that at the beginning of solidification not a solid solution but some graphite separates out which with sufficiently slow cooling in consequence of its small specific gravity would rise to the upper surface of the fluid metal. Here also we must finally reach the constituents, cementite, ferrite (plus traces of graphite).

Since this theory, proposed by Roozeboom, contradicts experience in many points, a fact that has already been noted by several writers,‡ the following experiments with the least objectionable material were performed in order to obtain further conclusions.

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* " Eisen und Stahl von Standpunkte der Phasenlehre," Zeitschrift f. phys. Chemie, 32, S. 439 (1900).

† Mother metal (?).— EDITOR.

‡ Heyn: "Labile und metastabile Gleichgewichte," in "Eisen-Kohlenstofflegierungen," Zeitschrift f. Elektrochemie, 1904.

In order to produce pure iron-carbon alloys, Swedish nail iron of the following composition,

C = 0.035 per cent,
Si = 0.002 per cent,
Mn = 0.019 per cent,
P = 0.037 per cent,
S = 0.002 per cent,
Slag = 0.40 per cent,

was melted with the purest sugar charcoal, which contained only traces of a residue. To prevent a reduction from silicic acid, graphite crucibles lined with magnesite were employed; in this
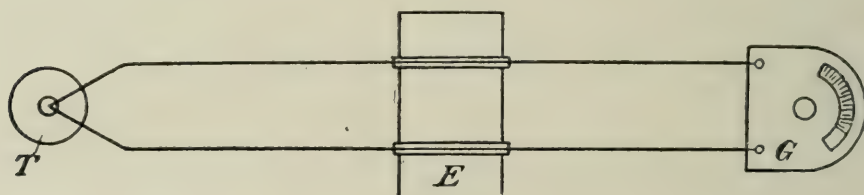
Fig 2
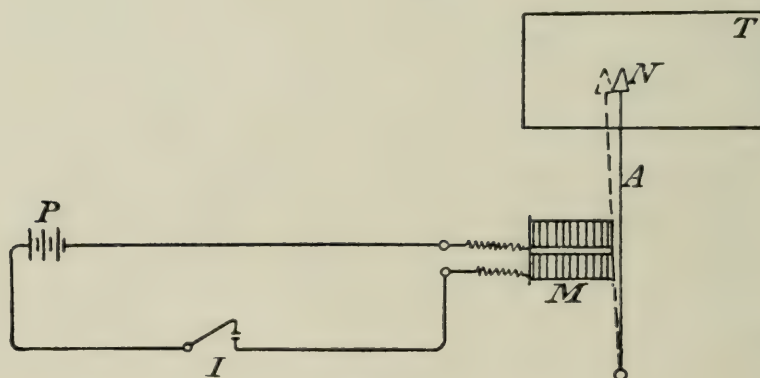
Fig 3.

manner it was successfully possible to produce varieties of cast iron which beside carbon contained only about 0.1 per cent of foreign bodies, as the following table of analyses shows.

To determine the curve of cooling a thermo-couple of platinum, platinum-rhodium T, protected by a thin porcelain tube, was introduced into the molten metal. (Fig. 2.)

Its cold junction was kept at 0° in an ice box E, and from there connected by copper wire with a voltmeter G. The cooling curves were recorded by means of the contrivance sketched in Fig. 3.

The drum T is set revolving at a regular rate by clockwork. At the same time the stylus N, by means of a screw-thread, is

advanced 2 millimeters at every revolution. In this way a continuous line is drawn on the white paper covering the surface of the cylinder T. In order to excite the needle to move at a given moment, a current is switched through the contact I into the electro-magnet M, whereby the arm A, which bears the stylus, is attracted. One observes now the course of the galvanometer needle and closes the current for an instant when the needle has traveled a determined interval, perhaps 10° C. The distance between two consecutive notches thus gives the number of seconds which the mass of metal needed to cool down to the specified temperature. In the present case 5 millimeters correspond to a second. For the graphic representation of the cooling of curves the temperatures were set down as the abscissas, the number of seconds as the ordinates, which are necessary to cool the metal about 10° C. If there arises at a given instant any retardation in the radiation of heat, this fact makes itself known by the more or less sudden rising of the ordinates.

COMPOSITION OF THE IRON-CARBON ALLOYS

No.	Total Carbon %	Graphite %	Cement Carbon %	Hardening Carbon %	Si %	Mn %	P %	S %	Remarks
1	2,56	0,00	1,69	0,87	0,019	0,019	0,035	0,012	
2	3,37	0,02	2,39	0,96	0,024	0,017	0,037	0,015	
3	3,56	0,008	2,53	1,022	0,019	0,020	0,037	0,012	
4	3,71	0,03	3,24	0,44	0,024	0,020	0,038	0,018	
5	3,81	0,02	3,18	0,61	0,010	0,020	0,036	0,012	
6	3,29	0,05	—	—	0,015	0,015	0,038	0,014	Curve No. 3
7	4,04	2,49	0,65	0,90	0,024	0,017	0,038	0,014	
8	2,94	0,04	2,08	0,82	0,006	0,018	0,037	0,014	Curve No. 1
9	2,98	0,02	2,05	0,91	0,045	0,021	0,037	0,015	
10	3,52	0,13	3,25	0,14	0,042	0,022	0,036	0,018	
11	4,04	1,75	2,28	0,01	0,039	0,018	0,040	0,014	Curve No. 7
12	3,66	0,51	1,90	1,25	0,041	0,014	0,037	0,020	
13	2,99	0,01	1,97	1,01	0,037	0,023	0,037	0,015	
14	3,76	2,33	0,95	0,48	0,009	0,021	0,038	0,017	Curve No. 4
15	4,82	3,31	0,77	0,74	0,011	0,021	0,038	0,017	
16	4,66	3,22	0,66	0,78	0,012	0,016	0,038	0,017	Curve No. 8
17	3,94	2,28	1,09	0,57	0,106	0,017	0,036	0,018	Curve No. 6
18	3,79	2,24	0,90	0,65	0,013	0,020	0,038	0,018	Curve No. 5
19	3,02	0,37	1,32	1,33	0,008	0,021	0,035	0,018	Curve No. 2
20	2,65	0,00	1,54	1,11	0,029	0,018	0,037	0,015	

The cooling curves of the alloys numbered 6, 8, 11, 14, 16, 17, 18 and 19 (see table) are shown in Figs. 4 to 11.*

* The German legends of these curves should be translated as follows: *Kurve* means curve; *Ges-C*, total carbon; *Grafit*, graphite; *Karbid-C*, cement carbon; *Hartungs-C*, hardening carbon.

Kurve № 1.
Material № 8.

Ges-C 2,94
Grafit 0,09
Karbid-C . . . 2,08
Härtungs-C 0,82

Fig. 4.

Kurve № 2.
Material № 13.
Ges.-C 3,02
Grafit 0,37
Karbid-C . . 1,32
Härtung-C 1,33

Fig. 5.

Kurve № 3.
Material № 6.
Ges-C 3,29
Grafit . . . 0,05

Fig. 6.

Kurve № 4.

Material № 14.

Ges -C	3,76
Grafit	2,33
Karbid -C	0,96
Härtung -C	0,48

Fig. 7.

Kurve № 5.

Material № 18.

Ges-C	3,79
Grafit	2,24
Karbid-C	0,90
Härtung-C	0,65

Fig. 8

Kurve N° 6.
Material N° 17.
Ges-C 3,94
Grafit 2,28
Karbid-C . 1,09
Härtungs-C 0,57

Fig. 9.

Kurve N° 7.
Material N° 11.
Ges-C 4,04
Grafit 1,75
Karbid-C . . 2,28
Härtungs C 0,01

Fig. 10.

Kurve N° 8.
Material N° 16.
Ges-C 4,66
Grafit 3,22
Karbid-C 0,56
Härtungs-C 0,78

Fig. 11.

As is clear from the analyses, the per cent of carbon in the tests rose to 4.82 per cent; so, for example, in No. 15, with 4.82 per cent carbon, according to the above theory, the difference between 4.82 and 4.30, that is, about 0.5, per cent graphite, or with the kilogram of metal used about 5 grains, ought to rise to the upper surface. Yet no trace of dross was found, the graphite being fully and evenly distributed through the mass of iron. One might raise as an objection the possibility that the graphite did not have time enough to rise to the upper surface; but then one must at least expect that in consequence of the effort to rise more graphite would be present in the upper part of the sample than in the lower part, which was not the case. On the other hand, if one reflects with what rapidity the dross or " kish " separates out of every high carbon pig iron on removal from the fu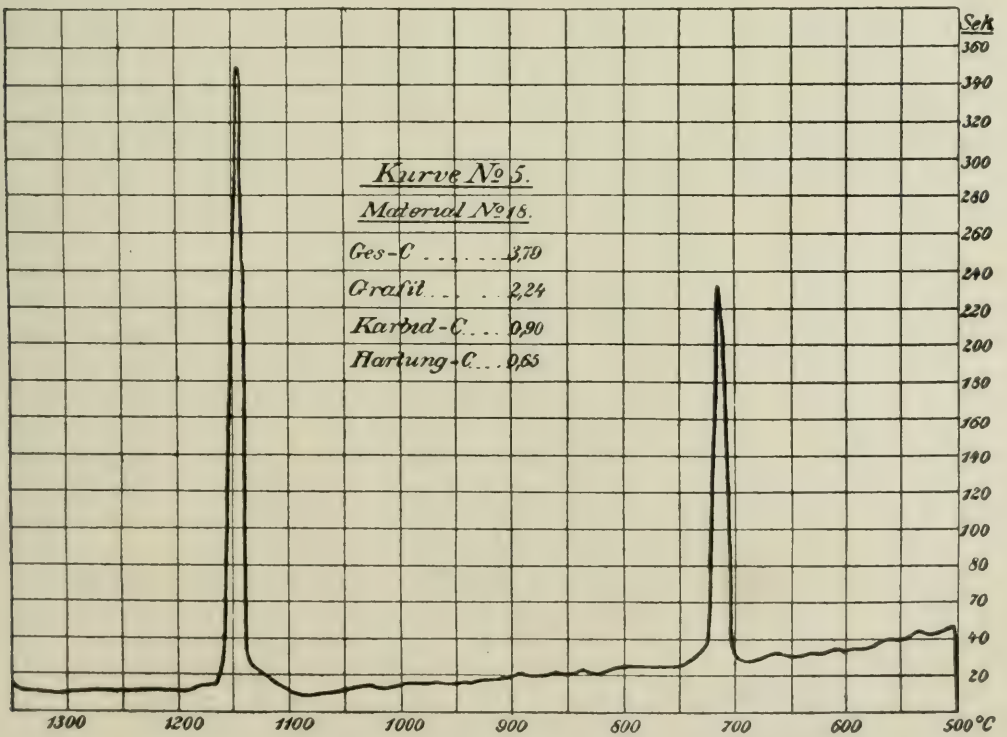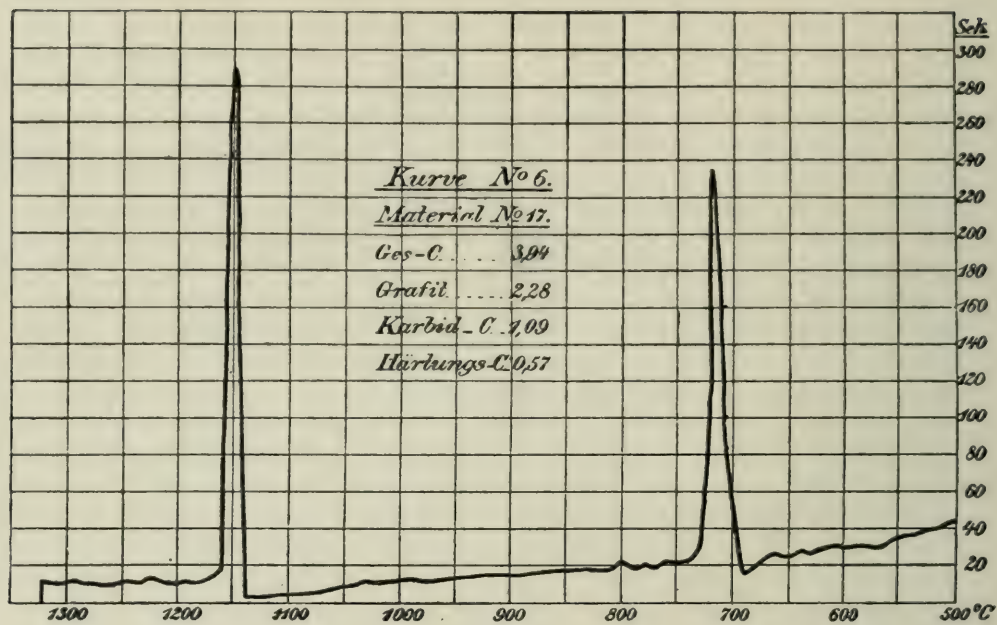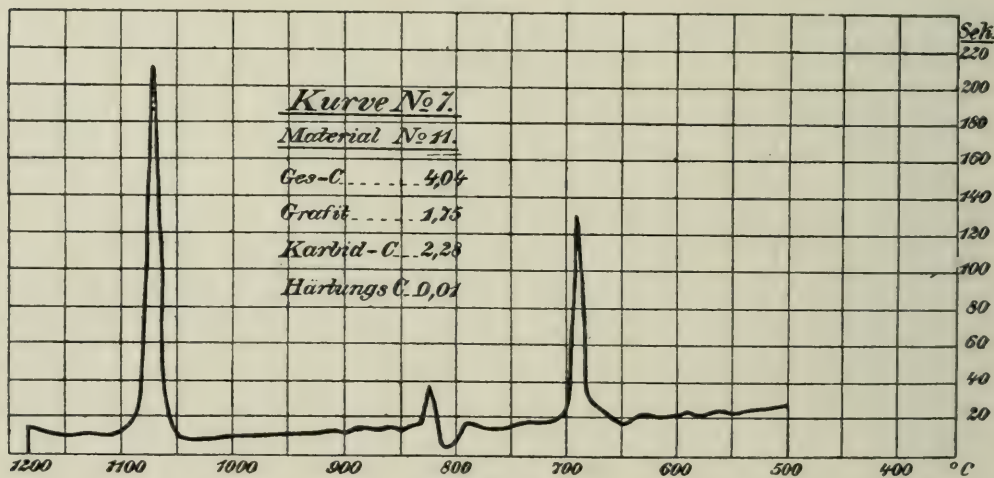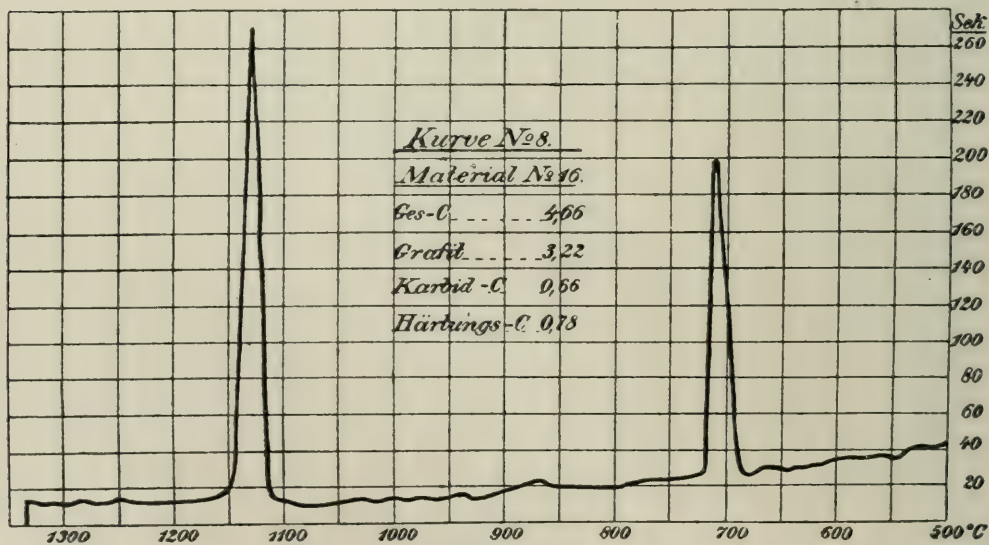rnace, the assumption will not be rejected that the graphite is not a primary but a secondary product which has only been able to form during or after the solidification of an alloy with a high per cent of carbon. Whether the graphite is a product of the disintegration of a solid solution of a carbide already separated, further investigations must prove. If the graphite were a primary product its formation, or at least retention, in the fluid mass, must be favored by as rapid cooling as possible, while by slow cooling the possibility of the formation of carbide according to the equation of Roozeboom, solid solution + graphite = carbide, must be favored. The opposite, however, is precisely the case. Slow cooling promotes the formation of graphite, quick cooling retards or hinders it completely. Certain kinds of pig iron which contain only a limited quantity of silicon show, on quick cooling, no noticeable formation of graphite; they show the characteristic fracture of white iron; if, however, they solidify slowly, graphite formation takes place.

Of this behavior of cast iron, generally known to the foundryman, use is made in producing the so-called chilled castings. Such parts of castings which should be hard, are quickly cooled, while the other parts cool slowly, and therefore show gray iron. (Armor plates at the Krupp works, rolls with hardened surface, wheels with hardened tread.)

Consideration of the analyses shows that any influence of the silicon in the small quantities in which it occurs in the present material is not perceptible in the matter of graphite formation.

No. 14 with 0.009 Si and 3.76 total carbon shows 2.33 per cent graphite, while No. 17, whose percentage of silicon was increased by the cracking of the crucible lining during fusion to 0.1 per cent, with 3.94 total carbon, contains only 2.28 per cent graphite. Since on the other hand (No. 5) a quantity of 0.01 per cent silicon in a percentage 3.8 per cent carbon was able to separate out only traces of graphite, we may rightly assume that the separation of graphite in these experiments is not to be ascribed to the silicon.

The even distribution of the graphite in gray iron has caused several authors to explain its origin as follows (Ledebur):

" Liquation from which the graphite distributed in iron arises can evidently take place only when the solidifying iron is able to hold less carbon in solution than the fluid iron; or, in other words, when the saturation point of the solidifying iron for carbon is lower than that of the fluid. But this is not the case with all iron in a fluid condition saturated with carbon iron, which contains only carbon without other foreign bodies, separates out no graphite. In order that graphite formation may take place, a second element beside the carbon must be present, which lessens the saturating point of the solidifying iron for carbon more than that of the fluid iron, so that during solidification it compels the carbon to crystallize out of its solution in the iron. In most cases where graphite formation takes place, silicon plays this part." *

The analyses in the table show graphite in eight cases, which in part rises to more than 3 per cent and amounts to 69 or 68 per cent of the total quantity of carbon. It is thus proved that, in the system iron-carbon, a second element need not be present for the formation of carbon.

Moreover, the study of the micro-photographs and the cooling curves demonstrates that the above explanation, however enlightening it may appear at first sight, expressed in this form, is not sufficient.

In gray iron (photograph 14) we find beside free graphite and pearlite, a few plates of cementite. Consequently the carbon contained in pearlite and cementite must represent for this case the dissolving capacity of the solidified iron for carbon,

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* A. Ledebur, " Handbuch der Eisenhüttenkunde," fourth edition, p. 310.

provided that with decreasing temperature it is not further diminished. According to the analysis the quantity of this carbon is equal to the total carbon less the graphite (No. 18) = 3.79 — 2.24 = 1.55 per cent, which thus for this case would be the maximum quantity of carbon dissolved in solid iron. If one calculates the same number for No. 5, a white iron of similar composition, we obtain 3.01 — 0.02 = 3.79 per cent, or a two and one-half times greater solubility in a compound otherwise nearly identical. Also with the other samples no approximately constant number for the maximum quantity of dissolved carbon can be deter-
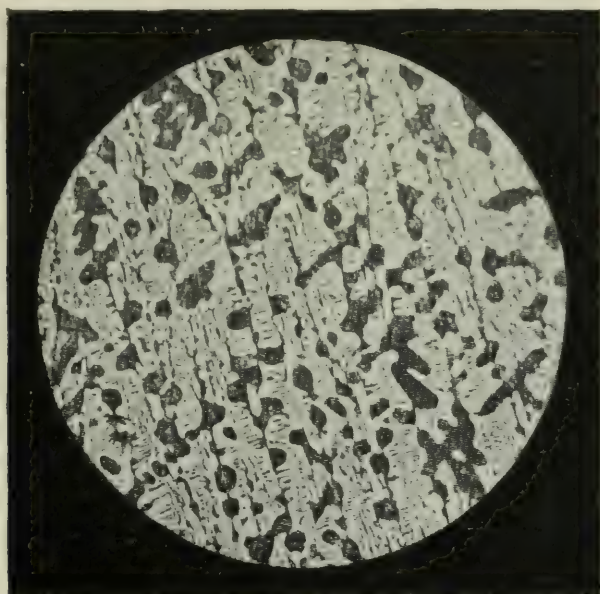
FIG. 12.   Magnified 50 diameters

mined. Photograph No. 16 is very instructive, showing a mottled iron, that is, a white iron in which areas of gray iron are more or less regularly scattered through the mass. On account of their immediate proximity, the gray and the white places cool with equal rapidity. Now experience proves that through slower cooling this iron would have become gray; so we have now before us an incomplete reaction whose final product is graphite and whose original constituent is either a solution of carbon in iron or cementite. This reaction which begins at the moment of solidification is not ended with the decrease of the temperature of solidification. The cooling curves show, especially for the gray iron, a delay in the fall of the temperature

which takes place not only at 1130° C. but also below this, a sign that the reaction begun at the point of solidification, 1130° C., continues still further with the loss of heat, whereby a retardation often of 10 to 15° C. is produced. In what way this retardation is influenced by the separated graphite, especially as to the quantitative determination of the liberated heat, suggests very interesting determinations.

Concerning the position and meaning of the point of solidification at 1130° C. there is still to be noticed that it shows few
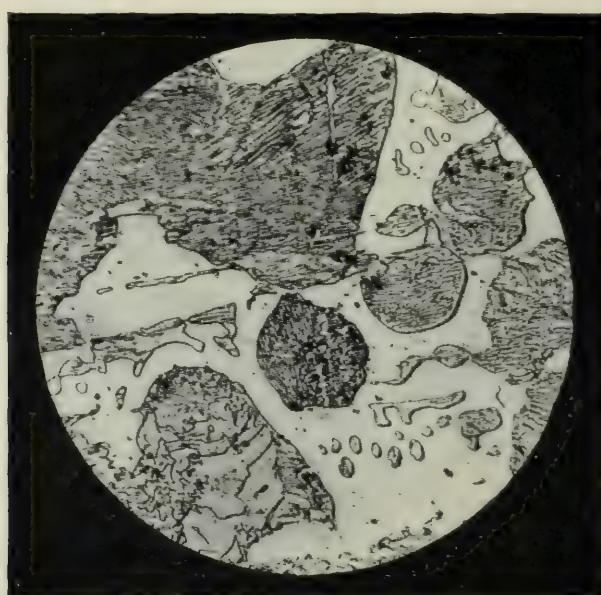
FIG. 13.   Magnified 500 diameters

variations in spite of the different percentages of carbon, as shown in the following table:

Curve .,....	1	2	3	4	5	6	7	8
Degree C.....	1132	1135	1112	1138	1141	1149	1122	1130
Total carbon .	2.94	3.02	3.29	3.76	3.79	3.94	4.04	4.66
Material no...	8	19	6	14	18	17	11	16

or at least it does not fall or rise perceptibly with increasing per cent of carbon.

By other experiments it is sufficiently proved that the melting point of iron is lowered by the presence of carbon. It is assumed that 1 per cent of carbon lowers it about 100° C.

This idea according to the above is not wholly correct. As soon as the melting point of iron with a certain per cent of carbon not yet more closely determined, has reached a certain minimum, apparently 1130° C., further addition of carbon is without influence on the lowering of the melting point.

Observing the cooling curves one is struck by their regular course between the two stopping places, 1135° and 700° C. In the diagram of Roberts-Austen we see that the cementite line ends rather suddenly at about 2 per cent, in spite of the fact that with this percentage of carbon a sudden change of the inner
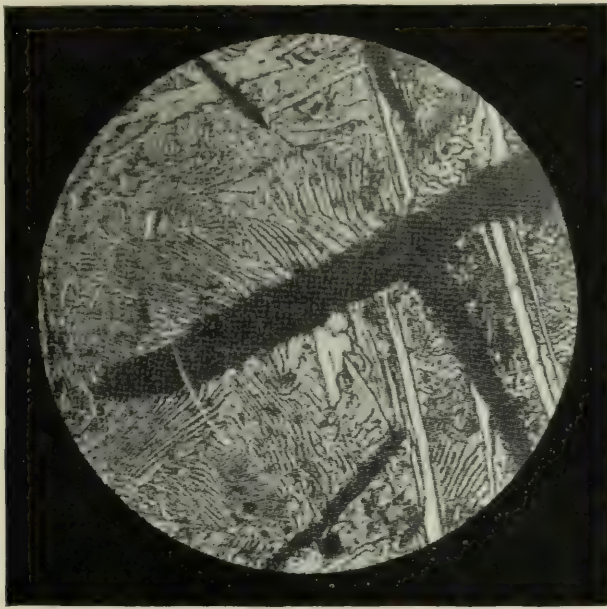
FIG. 14.   Magnified 500 diameters

structure of the alloys does not take place. On the contrary, this stopping place, which makes known the separation of super-fluous cementite (carbide), must become more evident the higher the percentage of carbon, thus also the quantity of cementite in the mass of metal. Roozeboom lays down the line of these retardations in alloys with a higher per cent of carbon than 2 per cent as horizontal from 1000° C. and assumes that the time of the formation of the cementite does not, therefore, become visible in the cooling curves because the evolution of heat is too slight to be noticeable on thorough retardations in the decrease of temperature.

Through recent experiments * small developments of heat have been proved at about 1000° C., at least in a number of cases; still Osmond † draws attention to the fact that in taking down cooling curves uncontrollable variations may take place in the decrease of temperature very easily on account of surface oxidation. Throughout the present experiments between 1130° and 700° no delays were noted; the one case (at 800° C.), Curve 7, might be traced to a mistake in observation.

Hence the conjecture of Osmond † and Heyn ‡ that the formation of cementite takes place at 1135° C., gains more

FIG. 15.   Magnified 500 diameters

probability. At this temperature during solidification carbide would separate out of white iron, while in gray iron the formation of graphite would occur, both processes being accompanied by considerable evolutions of heat. It is worth noticing that the stop or retardation in the fall of temperature often extends over an interval of only 10° C., and it will be reserved for later investigations to throw light on its exact meaning by extending the interval as much as possible.

* Carpenter and Keeling, " Journal of the Iron and Steel Institute," May, 1904.

† " Revue de Métallurgie," July, 1904, p. 437.

‡ Heyn: Article already cited.

The further course of the cooling brings at 700° another considerable delay; as we shall see from the metallographic investigation, this point corresponds to the temperature where carbide is insoluble in iron and consequently the entire mass of solid solution is divided into an intimately mechanical mixture of carbide and iron, cementite and ferrite. This intimate mixture bears the name of pearlite. In the curves given, this point is plain for both white and gray iron, corresponding to the considerable quantities of pearlite which are contained in

Fig. 16.   Magnified 500 diameters

both (photographs 12 to 17). The location of this point likewise varies, as is apparent from the following table:

Material number	8	19	6	14	18	17	11	16
Per cent carbon	2.94	3.02	3.29	3.76	3.79	3.94	4.04	4.66
Evolution of heat	702	710	700	708	716	719	692	710
Curve number	1	2	3	4	5	6	7	8

The variations lie outside of the possible errors in the measurement of the temperature; since, however, slight difference in the rapidity of cooling plainly alters the location of this point, the difference shown here might perhaps be traceable to such changes in the rapidity of cooling.

It is now a pleasant task to support or extend the knowledge gained from the thermal investigation of the material by an independent method. The microscope is an indispensable aid in the study of metals and alloys and could give more valuable information still if it were possible to observe the structure of a cross section at any temperature; since, however, the temperatures here considered forbid an actual use of the microscope, we must retard the structure peculiar to a mass of metal at a higher temperature and examine it at the ordinary temperature. We shall then surely produce an unstable condition and a ten-

FIG. 17.   Magnified 50 diameters

dency will always be at work to gradually restore the suppressed change.

Let us next observe slowly cooled materials. These could pass completely through both the changes at 1135° C. and those at 700° C. Cast iron free from graphite will thus contain free carbide as cementite and pearlite, the normal union of carbide and iron. Photograph 12 shows such an iron magnified 50 diameters. It consists of white fields which are dotted with numerous dark spots. Magnified still more (photograph 13) the latter prove to be a number of fine laminations which show the characteristic structure of the mixture, the pearlite. The

cementite is extremely hard and is not attacked by dilute acids. If a polished piece of such iron is treated with dilute acid, the cementite remains unattacked in relief while the separate ferrite plates of the pearlite between the cementite laminations are eaten away. In this way the pearlite plates act as a netting and give rise to the peculiar light effects which distinguish mother-of-pearl; hence the name pearlite.

In gray cast iron a part of the carbon is separated out as graphite and so there will appear beside cementite and pearlite black particles of graphite, which are generally torn away in
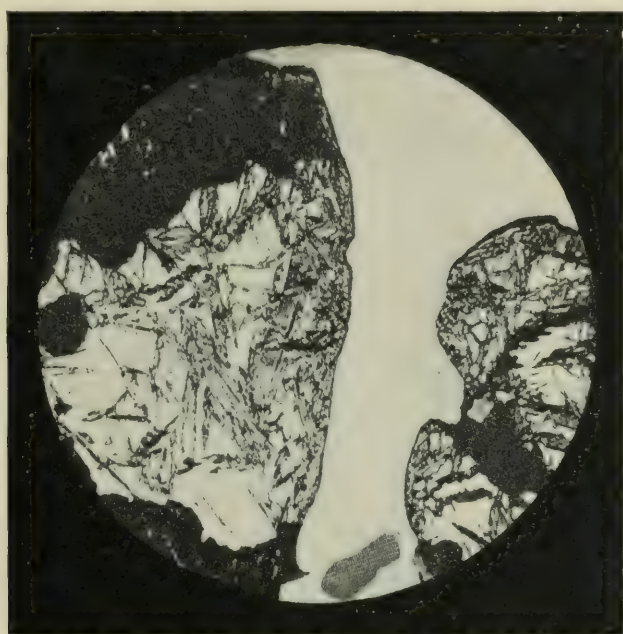
FIG. 18. Magnified 750 diameters

polishing. Photograph 14 shows such a structure magnified 500 diameters. It often happens, especially with very slow cooling, that the cementite plates of the pearlite are very far apart with a free field of ferrite between them. Since the ferrite is attacked but not stained by the agent used in this experiment, a 4 per cent solution of picric acid in alcohol, in order to distinguish the ferrite from the pearlite, one may make use of their different mineralogical hardness. Ferrite is scratched by a steel needle, but not cementite. The pearlite also is scratched, although only the projecting cementite laminations are touched by the needle. Since these are extremely thin and brittle, they are simply broken by the needle.

Photograph 15 shows such a scratch, which scratches the pearlite but not the cementite. The graphite runs through the structure in the form of wormlike veins; often it forms larger areas according as the cut separates the layers of graphite. In the last case the graphite is carried away by polishing the sample and one sees then in indistinct outline the structure of the neighboring fields. The immediate transition from white to gray pig iron of the same composition is shown by photograph 16, just mentioned above.

As we have already seen, during the cooling at 700° C. the
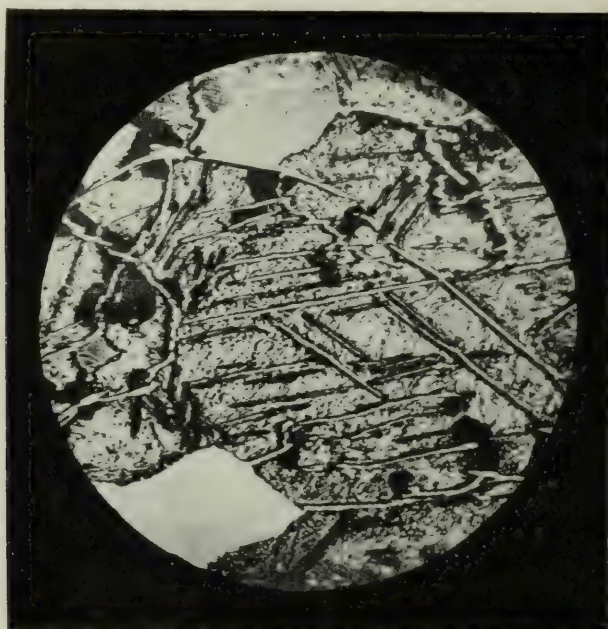
FIG. 19. Magnified 750 diameters

mother metal, consisting of 0.90 per cent carbon, changes into an intimate mixture of ferrite and cementite. This process is reversible; thus at this temperature the cementite dissolves in ferrite with formation of solid solution, which as a structural form has received the name of martensite.* If we fix the form of these crystals by sudden cooling (chilling) we obtain a regular structure which has the character of crystal clusters (places of cleavage, crystalline granulation). Photograph 17 shows a white cast iron chilled at 990° C. The white fields are unaltered cementite, broken through by a ground mass whose structure is

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* Austenite (?). — EDITOR.

given in photograph 18. We see that it consists of a light ground mass which is dotted with dark needles crossing each other in sharp corners or in triangles; and also of black irregular areas without recognizable form.

In order to understand the meaning of these three different parts, one must understand the process of solution taking place when heating to 700° C. and the possible changes later on quenching. It has been proved by H. Le Chatelier that when the cementite dissolves in the ferrite, there takes place a sudden decrease of volume followed by a sudden increase of volume,

FIG. 20. Magnified 750 diameters

after which the volume corresponding to the rising temperature slowly increases. This sudden decrease in volume corresponds to the formation of a structureless, easily stained constituent which Osmond has recognized and named troostite. Thus troostite will always appear when cementite is about to dissolve, and this will happen until the ground mass is saturated with cementite. The amount of troostite will be the smaller the higher the quenching temperature, because the crystals with increasing temperature are more quickly saturated with cementite, and also the longer the heating at a given temperature has continued, whereby time is given to the troostite to change into the crystalline martensite.

On heating we have thus at 900° C. the constituents cement-
ite, martensite and troostite. If the condition could be kept
completely unchanged through the cooling, only these three
constituents would occur. But since even sudden cooling
requires a certain time, the martensite can partly disintegrate.
Among the products of disintegration, whose character is still
uncertain, a specially striking one has been termed austenite*;
this is the light ground mass in photograph 18 which is crossed
by the darker needles of martensite. If the temperature is
increased still more, the amount of troostite plainly decreases,

FIG. 21.   Magnified 500 diameters

the disintegration of the crystals in martensite and austenite
increases, since the time which the material needs to pass from
1500° C. to 700° C. is naturally greater than when it cools down
from only 900° C. Photograph 19 shows beside cementite and
some troostite the needles of martensite encased by the mass
of austenite. Very interesting is the observation that the austen-
ite, which appears in high carbon steel only when quenched from
a very high temperature, is found in cast iron at considerably

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* The author here evidently reverses the generally accepted mean-
ings of austenite and martensite, by which the latter is considered as a
disintegration product of the former. — EDITOR.

lower temperatures; and also the simultaneous appearance of austenite beside troostite.

Quite similar conditions are found in gray cast iron. If we examine the iron in photograph 14, we see beside the pearlite only a few narrow streaks of cementite; the remainder is graphite. This finely divided cementite will naturally dissolve more easily than the great masses of the cementite in the white iron (photographs 12 and 13). Consequently the formation of troostite will not occur as abundantly as in the white iron; photograph 20 shows us a gray iron quenched at 900° C. Here the effort of
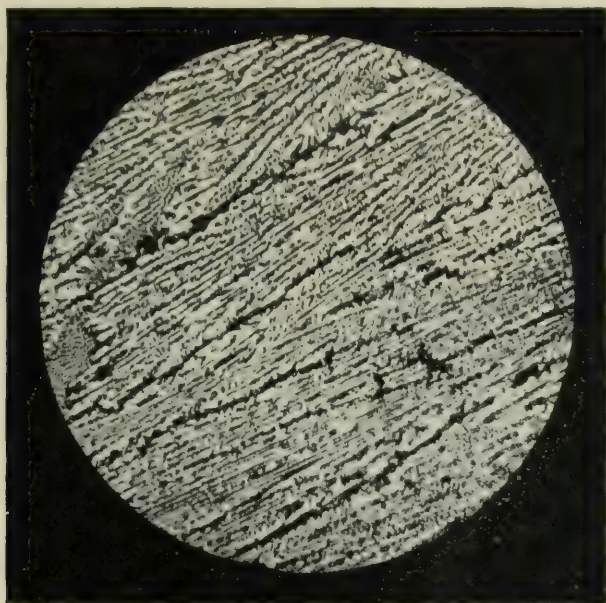
FIG. 22. Magnified 500 diameters

the dark martensite needles to cut into the mass of austenite in triangles is specially plainly seen. In the iron chilled at 1100° C., seen in photograph 21, the effort to disintegrate is still more plainly marked. At the same time one notices that the needles are colored light and the ground mass dark, a phenomenon to which Le Chatelier * has already called attention.

In the last examples we have observed only reversible processes. At the temperature of 700° C., cementite dissolves in ferrite to form martensite; if, instead of quenching in ice water, we had permitted the cooling to proceed slowly, as we

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* Le Chatelier: "L'austénite," "Revue de Métallurgie," 1904.

have seen, before the martensite would have become pearlite = cementite and ferrite. But if one heats iron, which above 700° C. contains free cementite, a considerable time at a high temperature (about 1000° C.), a non-reversible process occurs: carbide (cementite) = ferrite + (dissolved) carbon.

This process is illustrated in photographs 22–24. Photograph 22 shows a quickly cooled white iron which exhibits bright cementite in relatively fine division, dotted with a dark ground mass which contains carbon in solid solution. This material, kept for 50 hours at 980° C. in a vacuum, showed after slow
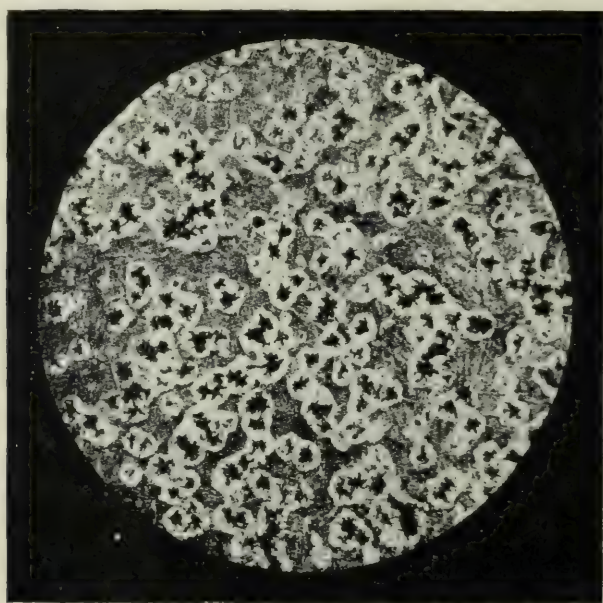
FIG. 23.   Magnified 50 diameters

cooling the structure of photograph 23, — magnified still more in 24. Black, irregular knots are surrounded by light areas; between the latter are streaks of pearlite. The material formerly as hard as glass, is easily filed, because of its composition, temper carbon, ferrite, pearlite. If the temper carbon is removed in some way, perhaps by oxidation, an iron remains which consists only of ferrite and pearlite, and so is malleable. This operation, which changes the white, brittle, non-malleable cast iron into a soft metal, is called annealing; the final product, annealed or malleable cast iron.

This process of the division of the cementite into ferrite and temper carbon has much bearing upon the theory. First of all,

it must be mentioned that the material which served for the experiments illustrated in 22 and 24 was almost free from Si, or at least did not contain more than 0.008 per cent of it; the total carbon amounted to 3.8 per cent, and it contained 0.09 per cent Mn, 0.008 per cent P and 0.01 per cent S.

Pure cementite is then not a stable compound at 1000° C., but divides into the elements iron and carbon. A clear proof that the dark areas within the ferrite areas are elementary carbon or some carbide rich in carbon, which, when treated with HNO_3, liberates carbon, would be hard to give.
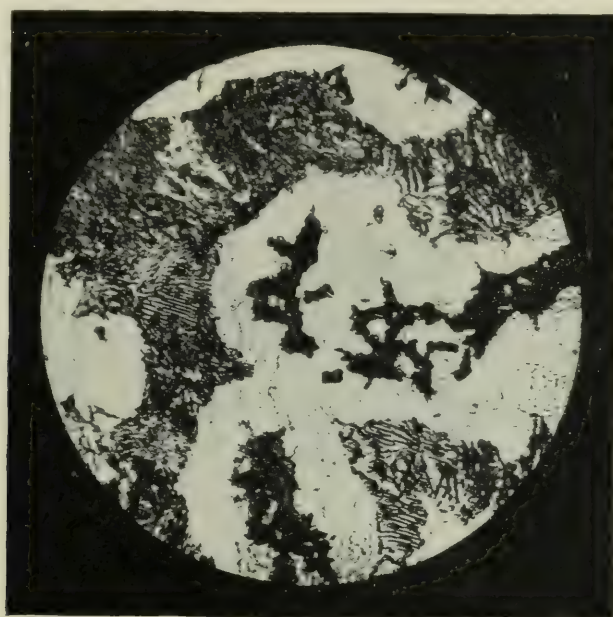
FIG. 24.   Magnified 500 diameters

When the division of the cementite has begun, it does not cease at the moment when all the superfluous cementite is decomposed, but possibly continues, till the formationof the system ferrite + temper carbon. The example given in 22 to 24 shows, beside pearlite (0.9 per cent carbon), much free ferrite (0.0 per cent carbon), or in the cross section about 0.4 per cent carbon, the remainder 3.8 — 0.4 = 3.4; that is, 89 per cent of the total carbon is temper carbon. This fact speaks very much in favor of Heyn's * assumption, which considers the system ferrite + carbon as stable and the other systems as phenomena of rapid cooling.

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* Heyn: Article cited.

Moreover, it is not admissible to determine the dissolving capacity of the iron for carbon by melting pure carbide obtained by treatment with acids and considering the carbon of the remaining mass of iron as the saturation point. According to the degree of the decomposition of the carbide before melting, the saturation point can amount to 90 per cent, as we have just seen, and a great part of the carbon will coat on the surface; how much of the latter will be taken up by the fluid metal depends mainly on the time, though also on other not well-known circumstances. To the latter belong, for example, the thickness of the

FIG. 25.   Magnified 500 diameters

carbon resting on the metal; these experiments have shown that with a light rust the carbonization of wrought iron to cast iron of 3.5 per cent took about 5 times as long as by means of heated sugar charcoal in otherwise identical circumstances.

Below 700° C. the formation of carbon from cementite in otherwise pure iron is not possible. Photograph 25 shows a white iron (with traces of graphite) after 50 hours at 650° C. The characteristic laminated structure of the pearlite is completely gone, while the separate cementite laminations have rolled together in small, irregular lumps. This form of the pearlite has been well named " granulated pearlite."

The laminations of which the pearlite is composed become plainer the slower the cooling from above 710° C.; if it cools rapidly, it remains, as we have seen, martensite. According to the rapidity of cooling there are more or less clearly marked transition forms, of which we have already noted one, troostite. Sorbite has also been distinguished, which, magnified very greatly, gives, to be sure, an indication of laminated structure, but is stained by certain reagents, which does not occur with pearlite. Whether sorbite and troostite are really different components is not easy to determine, but the assumption is possible that they

Fig. 26.   Magnified 500 diameters

are the ends of a series of transitional forms of martensite and pearlite, or vice versa.

Practically, as well as theoretically, it would be of the greatest importance if these processes could be chemically investigated. The discovery that the carbon (cementite) of annealed steel occurs in another state from the carbon in the quenched (martensite) steel led to the proof that in the slowly cooled steels a carbide of the composition Fe_3C is contained, which in dissolving the steel in dilute acids remains behind as a heavy powder and, as we have seen above, furnishes as cementite a constituent of the structure. It is striking that the quantitative determination of this carbide cannot be performed by dissolving the mate-

rial carefully in dilute acids. Photograph 26 shows us the structure of a white iron which was slowly cooled, hence consists only of free cementite and pearlite. The total carbon is 2.65 per cent, and ought, according to the customary method of determining carbide, remain completely in the carbide residue. Yet the calculation of the carbon contained in this residuum gave only 1.54 per cent, that is, a loss of 2.65 — 1.54 = 1.11 per cent carbon, about 41 per cent of the total carbon. Photograph 27 shows the structure of a slowly cooled gray iron with a total carbon content of 4.66 per cent. If we subtract from this the
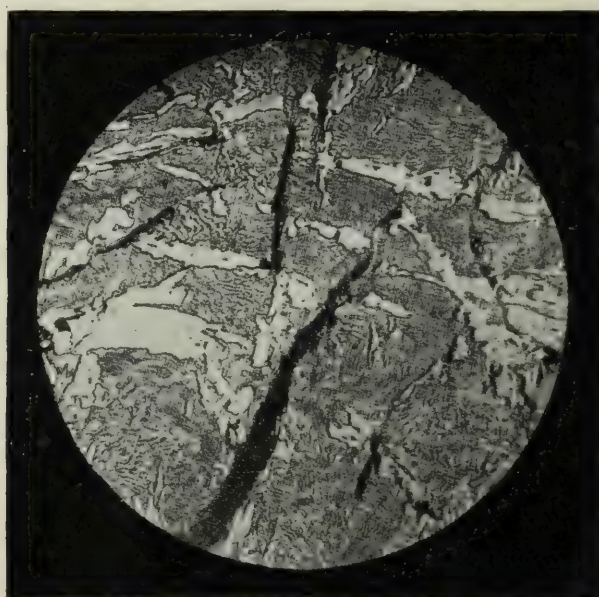
FIG. 27.   Magnified 500 diameters

graphite, 3.22, there remains 4.66 — 3.22 = 1.44 per cent, combined carbon. The direct determination gave 0.66 per cent carbon in the carbide, which again corresponds to a loss of 1.44—0.66 = 0.78 per cent of total combined carbon. In what way this loss, which is also to be noted in all the other tests, can be explained, could not be determined. Of course its regular appearance shows that the views concerning the composition of the different components of iron are not to be brought into agreement with the results of chemical analysis.

The view of Benedick * that the ferrite of the different

* " Recherches physiques et physico-chimiques sur l'acier au carbone," A. Felix, Leipzig.

varieties of iron with more than 0.5 per cent whole carbon could hold some carbon in solution, might perhaps pass as a sufficient explanation of the phenomenon for the kinds of steel which he examined, but is not satisfactory in order to make in the least plausible the causes of the great losses of carbon in cast iron.

In conclusion it is my pleasant duty to express my heartiest thanks to Messrs. Paul Oberhoffer and Paul Goerens, my colleagues, for their assistance on this essay.

THE APPLICATION OF DRY-AIR BLAST TO THE MANUFACTURE OF IRON *

By EDWARD DE MILLE CAMPBELL, Ann Arbor, Mich.

IN the discussion of Mr. Gayley's paper on the "Application of Dry-Air Blast to Manufacture of Iron," † most of the authors have attempted to explain the remarkable results solely on theoretical grounds.

As Mr. E. Windsor Richards has explained, Mr. Dawson showed more than one hundred years ago that blast furnaces are influenced by variation in the amount of moisture in the air, more fuel, as a rule, being required in summer than in winter. This fact has been a matter of general knowledge to blast-furnace men since Dawson's time, but they do not seem to have appreciated the extreme sensitiveness of a blast furnace to variations in atmospheric moisture, until Mr. Gayley demonstrated the remarkable improvement which can be brought about by reducing the

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* A discussion of the paper by Mr. James Gayley, read at the Lake Superior meeting, September, 1904, American Institute of Mining Engineers, Bethlehem meeting, 1906. Slightly abridged.

† Trans., xxxv, pp. 746 and 1022.

amount of water carried in by the blast to a small and prac-
tically constant amount.

Dr. Raymond seems to be the only one of those who have
contributed to the discussion of Mr. Gayley's paper who appre-
ciates the underlying cause of the great value of Mr. Gayley's
invention. The great economy in operation is not due to the
saving of energy required for dissociation of water in the blast,
which it has been shown by others does not exceed 3 or 4 per
cent of the total energy evolved by the fuel, but is due to uni-
formity of conditions in the hearth, which permits a uniform
temperature to be maintained in that part of the furnace. That
the great value of dry air is principally due to the elimination
of the daily hygrometric variations may be clearly seen from a
study of the observations made by me sixteen or seventeen years
ago, while I was chemist for the Dayton Coal and Iron Company,
of Dayton, Tenn.

Before going south, I had held a similar position with the
Sharon Iron Company at Sharon, Pa. One of the first things I
noticed on going to the Dayton furnace, which was so much
farther south than the one at Sharon, was that the southern
furnaces at that time apparently had much more difficulty in
running uniformly, especially in the winter months, than did
the furnaces which were located farther north. After watching
the furnaces carefully for some time, I noticed that the furnaces
usually took more charges during the night shift than during
the day. I also noticed that on several occasions, when there
was a marked change in the weather, the furnace seemed to be
influenced by the change. The only cause I could see for the
furnace driving faster at night than during the day time was
that at night there was apt to be a heavy precipitation of dew,
with consequent diminution in the amount of moisture blown
into the furnace. The effect of this was usually manifest about
9 or 10 P.M., when there was a marked increase in the rate of
driving, which was normally maintained until about the same
hour in the morning; that is, the furnace ordinarily responded
to the change in the amount of moisture within about four or
five hours after the change had taken place. After observing the
furnace for some months, I became so impressed with the sen-
sitiveness of the blast furnace to atmospheric changes, that I
decided to make a systematic set of observations to determine

to what extent these changes affected the operation of the furnace.

To this end an ordinary hygrometer, consisting of a dry-bulb thermometer and a second thermometer, the bulb of which was wrapped in lamp-wicking dipping in water, was constructed. This hygrometer was placed in the stock-house, where there was a free circulation of air, but protected from direct drafts, which would cause excessive evaporation from the wet bulb. From the difference in the reading of the dry-bulb and wet-bulb thermometers, the dew-point (the temperature at which the air would be saturated with moisture) was determined. The dew-point having been determined, the amount of moisture per cubic foot of air was found from physical tables, and the figures so found were used as a basis for calculating the amount of coke required to dissociate the water carried in by the blast. Four readings per day were made, at 5 A.M., 12 M., 5 P.M. and midnight. At the time the readings were taken to determine the dew-point, the number of revolutions of the blowing engines was also recorded.

From the furnace books, the number of tons of each grade of iron produced daily was taken, as well as the number of pounds of ore charged into the furnace for each unit weight of fuel.

In order to determine the amount of coke required per day, for the decomposition of the moisture introduced by the blast, the following assumptions were made: (1) That the blast was actually on twenty-three out of twenty-four hours, a loss of one hour being allowed for the time during which the blast was off for flushing the cinder or casting the iron; (2) on account of the inefficiency of the blowing engines and leaks in the hot-blast stoves, mains, etc., that 60 per cent only of the piston displacement actually entered the furnace; (3) that nine tenths of the carbon of the coke reached the neighborhood of the tuyères, where the heat developed by its combustion to carbon monoxide was available for dissociating the water vapor.

The coke we were required to use contained an average of 21 per cent of ash and about 75 per cent of carbon. I selected the figures, twenty-three hour — 60 per cent piston displacement and 90 per cent of the carbon of the coke reaching the tuyères —as conservative figures. If the blast were on more than twenty-

three hours, or more than 60 per cent of the piston displacement entered the furnace, or less than 90 per cent of the carbon of the coke reached the tuyères, the figure showing the amount of coke required for the decomposition of the moisture would be correspondingly increased.

The term " grade heat " was one invented in order to enable the temperature of the furnace, so far as it was indicated by the kind of iron being made, to be expressed in figures and recorded graphically. At the time these notes were made we had no reliable figures showing the temperature existing in the lower part of the blast furnace. Also, at this same time, the iron was graded by fracture as follows, the grades being arranged according to the temperature of the furnace at the time the iron was produced, — white, mottled, gray forge, No. 3 foundry, No. 2 foundry, No. 1 foundry, No. 1 soft, No. 2 soft and silver gray or glazed iron. Since the furnace was usually worked on foundry iron, a grade heat of 1.00 was empirically adopted as representing the temperature existing in the furnace at the time No. 1 foundry iron was being produced. If the furnace cooled off sufficiently to produce No. 2 foundry iron, the grade heat, 0.98, was adopted; similarly, 0.96 represented No. 3 foundry iron, 0.93 gray forge, 0.90 mottled and 0.88 was the grade heat employed when the furnace was cold enough to produce white iron. On the other hand, when the furnace was hotter than was necessary to produce No. 1 foundry iron, a grade heat of 1.02 was employed to indicate No. 1 soft iron, and 1.03 to indicate No. 2 soft; and if the furnace became hot enough to produce silver gray or glazed iron, this was indicated by a grade heat of 1.05. While these grade heats probably do not express the exact ratios of the temperature existing in a blast furnace at the time the different grades of iron are being produced, they do represent the relative temperature, and afford a means of expressing, in figures, the conditions of a blast furnace. In order to determine the grade heat for the blast furnace for any given day, resort was made to the daily report of the iron grades. From this report the number of tons of each grade of iron was obtained, and these amounts were each multiplied by the proper grade heat, and the sum of these products was divided by the total number of tons produced. For example, if the furnace made 105 tons in a day, consisting of 40

tons of No. 2 foundry, 30 tons of No. 3 foundry, and 35 tons of gray forge, the mean grade heat would be found as follows:

$$40 \times 0.98 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 39.2$$
$$30 \times 0.96 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 28.8$$
$$35 \times 0.93 \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 32.55$$
$$\overline{100.55}$$

$100.55 + 105 = 0.957$, the mean grade heat of the day.

Daily observations were made on the two blast furnaces of the company from July, 1888, to August, 1890, inclusive, at which latter time I resigned my position to accept the chair of Metallurgy and Analytical Chemistry at the University of Michigan. The results of all these observations were plotted in curves which showed the dew-point, yield of iron per day, the grade heat and the burden of ore per buggy.

From the original curves, extending over a period of twenty-six months, which have been kindly lent to me by Mr. W. J. Isaacson (managing director of the Dayton Coal and Iron Company), I have selected sixteen typical instances showing the influence of variations in the dew-point on the working of the furnace. The results of these variations are given in Table I, and the data of all the sections of this table are shown graphically in Figs. 1 to 16.*

A study of these curves revealed some exceedingly interesting relations, especially the sensitiveness of a well-burdened furnace to atmospheric changes. In studying these curves, it must be borne in mind that the variations in atmospheric moisture are not the only irregularities in the material entering the furnace, because the solid material — coke, iron ore and limestone — are liable to vary from day to day. The company operated furnaces No. 1 and No. 2, which were apparently alike in size (75 feet high, 18 feet bosh, 9 feet hearth), each having eight 6-inch tuyères. No. 1 furnace was considerably further from the engine-house than was No. 2, which seemed to be about the only difference in the furnaces, yet No. 1 would never average as large a yield of iron, nor would it carry as heavy an ore burden as would No. 2. A study of the curves shows that while No. 1 furnace was in general affected by atmospheric changes, like No. 2, the extent of the changes was not usually as strongly

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* Not reproduced here. — EDITOR.

marked as in the latter furnace. If a furnace is carrying a full burden of ore, the heat being well concentrated in the hearth, with a cool top and the dew-point rises, — that is, the amount of moisture introduced at the tuyères is increased, — the effect of this begins to show within five or six hours, either through a falling off in the grade heat alone, or in a cooling off of the furnace accompanied by slower driving. On the other hand, if a furnace is running normally, with the heat well down in the hearth, with the top cool, and there is a fall in the dew-point, the effect is first shown by a rise in the grade heat and an increase in the rate of driving, that is, an increase in the output of iron. If the dew-point remains persistently low, and the ore burden is not increased, the effect is frequently to raise the width of the fusion zone, after two, three, or sometimes four days, the grade heat often falling off somewhat as the height of the fusion zone is increased. If, after several days running with an abnormally high fusion zone, the dew-point again rises, the effect is frequently to lower the fusion zone suddenly, coincident with the falling off of the grade heat. This sudden lowering of the fusion zone causes the stock to come in contact with that portion of the bosh walls which was superheated during the period of low dew-point, and tends to stick and form scaffolds. These incipient scaffolds afterward give way under the weight of the stock, causing slips and slides, with accompanying troubles.

If a furnace is normally " underburdened," if such an expression may be used, a change in atmospheric moisture does not usually produce as marked an effect on the furnace, since the total heat energy developed in the furnace is greater than should be required, and the effect of an absorption of heat by increased amount of moisture in the blast would not be as noticeable as if the furnace were carrying a full burden. On the other hand, No. 1 furnace, which was usually underburdened, had a greater tendency to form incipient scaffolds than did No. 2, which usually carried a full burden.

Up to the time these systematic observations were made, much trouble has always been experienced from scaffolds, especially during the months of January and February. During these months in the South, the fluctuations in the moisture is apt to be very great, and consequently the conditions conducive to the formation of scaffolds occur most frequently. Moreover,

the dew-point is apt to be low for several days, thus tending to increase the height of the fusion zone, and then rise quite rapidly, causing a sudden contraction in the fusion zone, with a tendency toward the formation of scaffolds. When the most frequent cause of these irregularities was appreciated, proper steps were taken whenever a marked change in the dew-point indicated the necessity. By careful controlling of the burden, etc., according to the indications, as shown by the hygrometer, many of these irregularities, which had previously been such a serious cause of trouble, could be overcome. Thus, in many instances, when the foundry man perceived that the dew-point was rapidly rising, he would put in an extra charge of fuel without any ore. This extra fuel would prevent the grade heat from falling, but, as it was not registered in the furnace book, it is not shown in the curves.

In the summer months, although the dew-point was very high, the fluctuations were usually confined to rather narrow limits, so that the furnace would not carry as heavy an ore burden as during the colder months; but the work of the furnace was apt to be more regular than during the winter months.

While it is extremely difficult to express in numbers the exact saving that would be effected in blast-furnace practice by removal of the moisture from the air, my two years of close observation of the influence of atmospheric changes on the furnace operation convinced me that at least two thirds, if not three fourths, of the irregularities in blast-furnace running were directly attributable to the varying amount of moisture entering the furnace. The lack of uniformity in the grade of the iron, and the irregularity in the running of the furnace, are due not so much to the amount of moisture entering into the furnace at a given time as the fluctuations in the amount of moisture on different days.

I cannot but feel that if Mr. Gayley has succeeded, as he apparently has, in reducing the amount of moisture to a small and constant amount, his invention will eventually prove to be the most important advance in the metallurgy of pig iron since the introduction by Neilson of the hot blast, more than seventy-five years ago.

A GRAPHIC METHOD FOR THE COMPUTATION OF BLAST-FURNACE CHARGES *

By C. O. BANNISTER

SEVERAL methods have been devised for the rapid calculation of blast-furnace charges, among the most important of which are:

1. Professor Balling's diagrams,† based on the similarity of triangles which require an arrangement for indicating the position of lines parallel to given lines on the diagram.

2. A method devised by Mr. H. C. Jenkins, ‡ which requires the use of a slide.

3. A slide-rule devised by Mr. A. Wingham.§

The following method is somewhat similar to the second of the above, but requires a sheet of squared paper only, no slide or rule being necessary.

Coördinates are taken, representing bases and acids, the abscissæ representing the bases (lime, magnesia, etc.), the ordinates representing silica.

Preparation of the Diagram. — The monosilicate of lime slag consists of $2CaO, SiO_2$, that is, from atomic weights, 112 parts of lime will require 60 parts of silica, therefore 11.2 parts of lime will require 6 parts of silica, and 22.4 parts of lime will require 12 parts of silica. The points representing these figures are now marked on the squared paper and joined by means of a straight line, which, if produced, will, of course, pass through the origin. The same principle is carried out in respect to each of the other bases, and thus a series of straight lines is obtained.

Diagram No. 1 (Plate XIX) is prepared for the calculation of iron blast-furnace charges, in which as a rule only CaO, MgO, Al_2O_3, $CaCO_3$ and SiO_2 have to be considered.

Diagram No. 2 (Plate XX) is for the calculation of copper and lead blast-furnace charges, as other bases such as FeO, MnO,

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* Transactions of the Institution of Mining and Metallurgy, Vol. xiii.

† Balling. "Metallurgische Chemie," Bonn, 1882. An Introduction to the Study of Metallurgy. Prof. Sir W. C. Roberts-Austen, 1894, p. 214.

‡ "Journal of the Iron and Steel Institute," 1891, No. 1, p. 151.

§ *Idem*, 1892, No. 1, p. 233.

DIAGRAM N°1
FOR THE CALCULATION OF
IRON BLAST FURNACE CHARGES
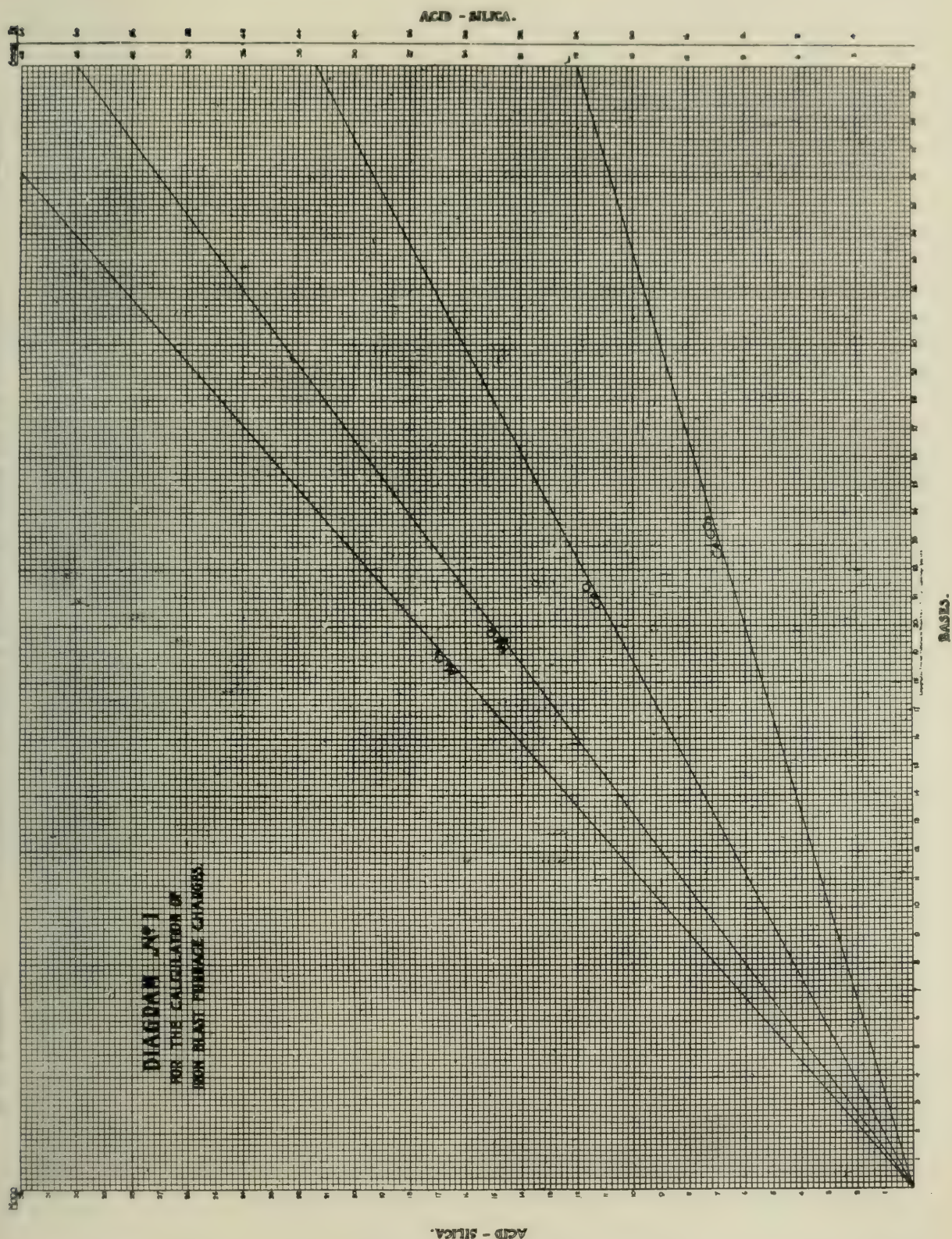
BaO, etc., have been introduced, and also, at the suggestion of Capt. C. C. Longridge, lines have been introduced for the calculation of the amount of SiO_2 required to flux off Fe and Mn when these are returned as metals and not as the corresponding bases in the analyses.

Both diagrams may be used for regulating the charging, from analyses of the slags produced.

Bisilicate and sesquisilicate slags can be calculated on the same diagrams by using those silica figures marked " Bi " and " Sesqui. "

Example of the Calculation of an Iron Blast-Furnace Charge. — Suppose we take an iron ore containing as gangue:

Alumina . . . .   7.9 per cent.
Lime . . . .   7.5   ,,
Magnesia . . . . . : . . . .   3.8   ,,
Silica . . . .   15.8   ,,

On referring to diagram No. 1 we find that

the 7.9 parts of Al_2O_3 will require   6.95 parts of SiO_2
,, 7.5   ,,   ,, CaO   ,,   ,,   4.00   ,,   ,,   ,,
,, 3.8   ,,   ,, MgO   ,,   ,,   2.85   ,,   ,,   ,,

and total bases   ,,   ,,   13.80   ,,   ,,   ,,

Therefore the excess of SiO_2 in the ore requiring to be fluxed off will be $15.8 - 13.8 = 2$.

On again referring to the diagram, we find that

2 parts of SiO_2 require 3.7 parts of CaO_1,
or, 2   ,,   ,, SiO_2 ,,   6.7   ,,   ,, $CaCO_3$.

That is to say, every 100 tons of this ore will require 3.7 tons of lime or 6.7 tons of limestone in order to produce a monosilicate slag.

Allowance can be made for the ash of the fuel used, and for each per cent of sulphur in the fuel 3 tons of limestone must be added to the charge for every 100 tons of fuel used; thus, if coke containing 1.2 per cent sulphur is being used, then 3.6 tons of limestone must be added for every 100 tons of coke charged.

If the limestone used is siliceous, the amount of limestone required to flux off this silica can be obtained from the diagram, and this figure subtracted from the total $CaCO_3$ in the limestone, and the resulting figure used as the available fluxing material.

ACID - SILICA.

ACID - SILICA.

BASES.

DIAGRAM N° 2
FOR THE CALCULATION OF
BLAST FURNACE CHARGES
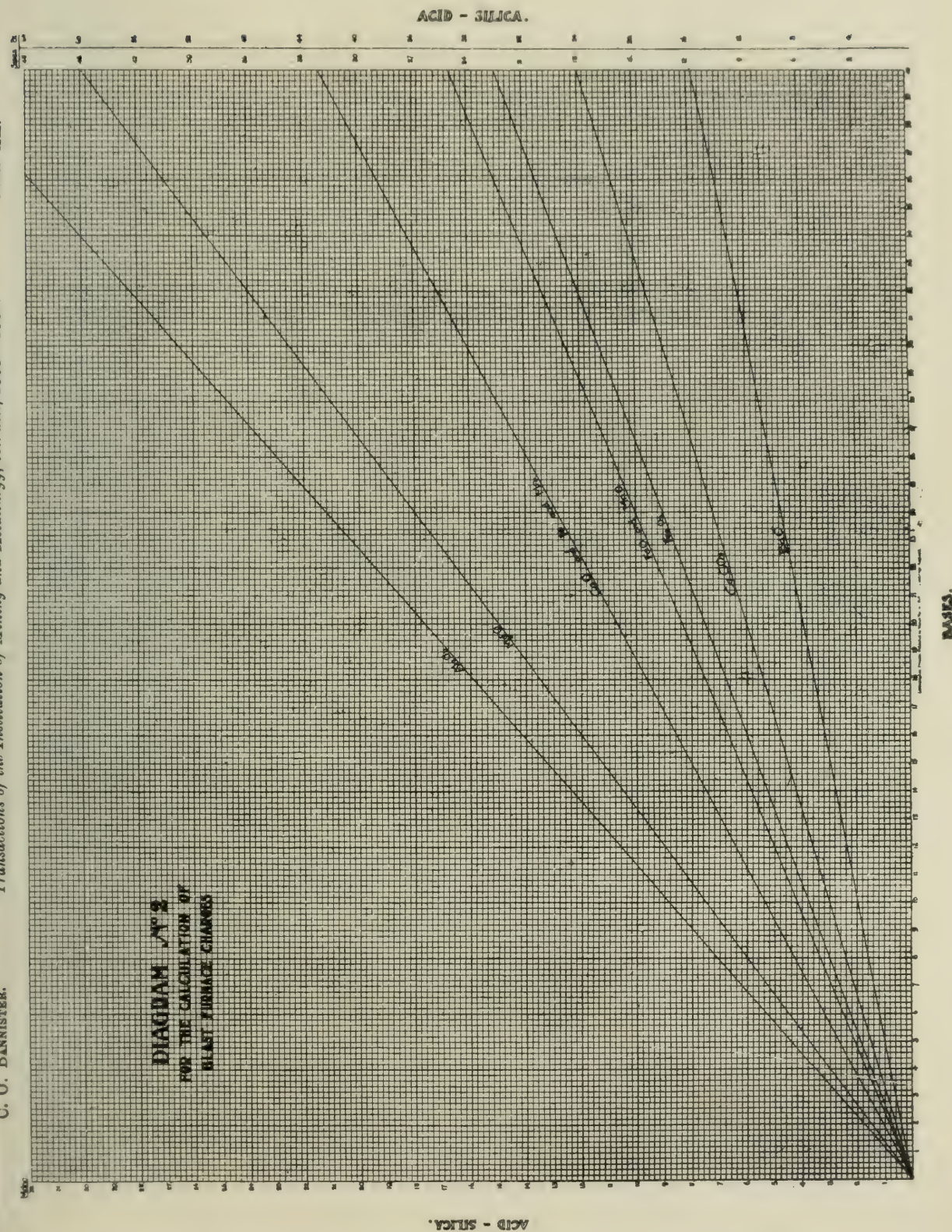
Example of the Method of Regulating the Charge from the Analysis of the Slag Produced. — The following is the composition of a slag from copper blast furnace, supposed to be making a bisilicate:

Silica. . . . . 48.2 per cent
Alumina . . . .   6.4   ,,
Lime . . . . 25.4   ,,
Magnesia . . . .   3.5   ,,
Ferrous oxide . . . . 12.6   ,,
Barium oxide . . . .   3.0   ,,

On referring to diagram No. 2 we find that

the   6.4 parts of Al_2O_3 flux off 11.2 parts of SiO_2
,,   25.4   ,,   CaO   ,,   27.2   ,,   ,,
,,   3.5   ,,   MgO   ,,   5.3   ,,   ,,
,,   12.6   ,,   FeO   ,,   10.5   ,,   ,,
,,   3.0   ,,   BaO.   ,,   1.2   ,,   ,,
                                   ─────
and the total bases   ,,   55.4   ,,   ,,

That is to say, there is sufficient base in the slag to form a bisilicate with 55.4 parts of silica, but from the analysis we find there is only present 48.2 per cent; the difference between these figures, 7.2, gives the amount of SiO_2 which could be fluxed off by the excess of bases in the slag.

To form a bisilicate with 7.2 parts of SiO_2 requires 6.7 parts of CaO or 12 parts of $CaCO_3$; therefore, for every 100 tons of slag produced in the furnace, 6.7 tons of lime or 12 tons of limestone have been added in excess.

OPEN-HEARTH STEEL CASTINGS *

By W. M. CARR

FURNACE CONSTRUCTION

IN American practice, when larger tonnages in output are sought, the general capacity of an open-hearth furnace working on castings is about 20 tons per heat. This capacity approaches the maximum that can be economically handled in jobbing shops, and will amply represent a general rule. Larger tonnages may be occasionally needed if the class of product is in the shape of heavy work requiring but a few molds to receive a heat of steel and consuming but a moderate interval of time to pour them; but in cases of a heat of steel to be put into a large number of molds, the pouring time may be so extended that the metal will lose its temperature. Therefore, charges exceeding 20 tons for miscellaneous castings are apt to result in losses due to cold steel. The cut given herewith shows the usual lines of a modern stationary furnace of 20 tons' capacity. The lines are the ultimate of experience in various plants and embody the best that is obtainable for that type of furnace at the present time. As they are only representative, they may be subject to some minor changes which may be dictated by necessities arising from local conditions in erecting. The principles of construction are the same in both acid and basic furnaces, differences occurring in the character of the materials forming the hearth linings. Generally the furnaces are of the stationary type. In some plants will be found furnaces of the rolling or tilting kinds, each having some good points in its favor. From the viewpoint of cheapness of construction, the stationary furnace holds the ground. Movable hearth types call for costly mechanical installation not required in stationary units. A potent argument in favor of the movable (rolling or tilting) furnace is the ability offered to completely drain the hearth at the end of a melt, thus emptying any pools that may form in the bottom due to excessive scorification, and the ease with which they can be readily repaired with proper refractories. In stationary furnaces much time is lost, with much discomfort

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* " The Foundry," February, 1906.

to the workmen in emptying pools or " puddles " by means of rabbles or scrapers. They cannot be thoroughly drained by
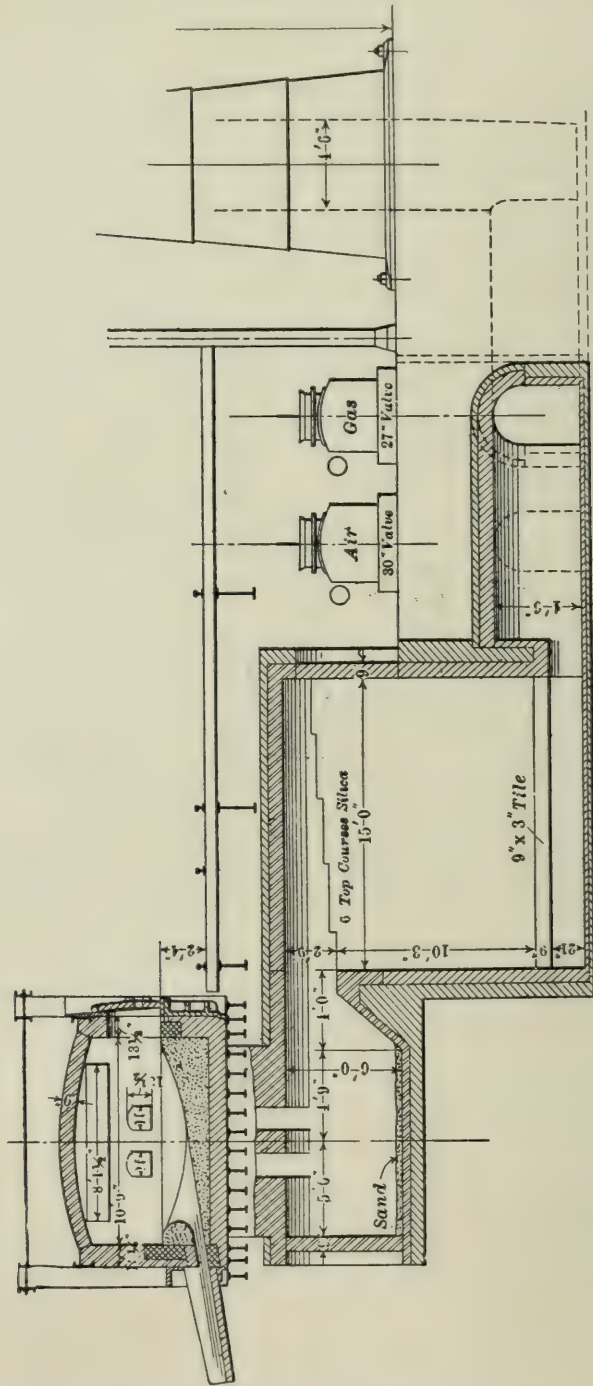
such means, and the subsequent patching may or may not be satisfactorily accomplished. The patching may become loosened in a succeeding melt. Such difficulties are more liable to

happen in basic bottoms than on acid. Another argument in favor of the movable furnaces is that the tapping hole troubles are eliminated. In stationary furnaces difficulties and annoying delays are encountered through "hard-taps" as a result of the materials used to temporarily close the tapping hole becoming fused or hardened and offering great resistance to tools necessary to open it at the proper time. In well ordered plants such difficulties are a rare occurrence, but still the risk exists. With a movable furnace the tapping hole is never tamped or closed, so that there is always the assurance that the metal can be drawn off when desired. Against these favorable considerations is the comparatively heavier first cost of the movable furnaces over the stationary, so that the question as to which type is to be approved will remain a debatable one. However, the relative volumes in regard to hearth area, regenerator chambers, etc., on the basis of the capacity of output per heat will be the same in any style of open-hearth furnace. The next in order will be some general rules as to points of construction and volumes for a 20-ton unit:

First. — Construction.

The metal work, such as buck stays, tie-rods, hearth pan, doors, etc., should be of rigid construction to withstand heavy duty due to brick-work expansion when the furnace is at full working heat   All walls should be bound at the ends. Rolled shapes should be used whenever possible. Skew backs of all arches should be braced by the binding, particularly those of the roof. In the regenerator chambers the ends of all outside or partition walls should be bound, as should the ports, because the brick expansion may cause leaks and permit ignition of the gas before it reaches the working body of the furnace. Study well the conditions of subsoil at selected site before putting in foundation. Foundations should be of rigid and of first-class masonry, to guard against irregular setting. They should be of hard red brick, laid in cement or concrete. No part of the furnace structure should extend below the lowest point at which water may be found. Water is an enemy to smooth furnace operation if it should find its way into flues or chambers. All underground flues not protected by clay should have an outside course of red brick.

Reversing valves should be of such construction that leak-

Fore Plate Level

Charging Floor
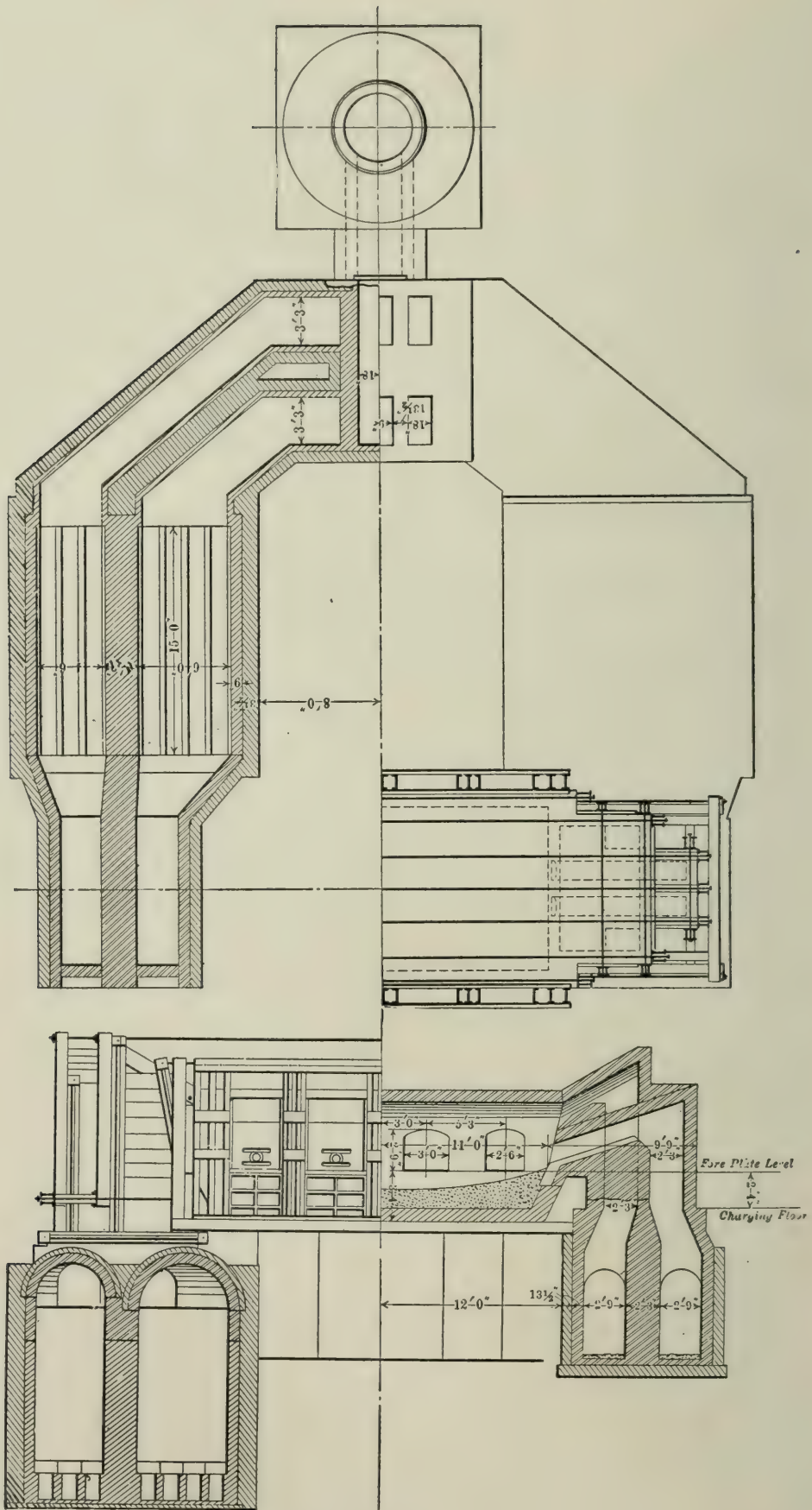
ages and loss of gas will not occur when operated. There are two distinct types, one known as the " butterfly valve " and another as the " turtleback." The latter is water sealed, which is an advantage. The stack should be of such construction as will induce a good draught, depending upon the damper for regulation.

Whenever possible, the doors, door frames and furnace fronts should be water cooled, features which add to the operator's comfort in watching his furnace. The cost of installation and maintenance may be heavy, but will result in a longer life for the parts and a consequent lessening of their repairs, offsetting the first cost. This arrangement is only possible on stationary furnaces. On movable ones the piping connections, etc., would be too complicated.

All flues, excepting those leading from the uptakes to the furnace body, should be roomy, to prevent choking and cutting by the deposit and heat of waste gases. Roominess is an essential in flues or conduits connecting the gas producers with the regulating and reversing valves, and it is good practice to have such conductors above ground the entire distance, to allow ready access to clean out unavoidable accumulations of soot and tar. Gas flues or uptakes leading to furnace body should be built with fake arches in their back walls, so that they can readily be repaired when badly cut without disturbing the rest of the furnace. They should also slope towards the hearth so that the incoming gas will be directed downwardly and impinge upon the stock or charge. The air port will also have the same direction; with the gas and air inlets and outlets working properly, the sheet of flame will be kept away from the roof and guard against burning or cutting that part.

Second. — Areas and volumes.

The hearth length of an open-hearth furnace should be as great as possible, in order that the greatest possible benefit be derived from the calorific value of the fuel. An undue shortening would be wasteful because the heat of combustion would be spent in the outgoing and at the sacrifice of fuel consumption and excessive cutting of outlets leading to chambers, meaning an increased cost in furnace repairs.

Practical experience has taught that a 20-ton furnace can be safely operated with a hearth length of 20 to 25 feet and a width of 9 to 11 feet. The total area of hearth surface will work

out to very close to 9 square feet per ton of capacity. The width is limited to a maximum of 15 feet because furnace operatives cannot throw a shovelful of refractory material much over that distance to reach the back wall. Another is an awkward spring or arched roof with necessary skew backs to support. Generally the length will be 2 to 2½ times the width.

The depth of the fully lined hearth will depend upon the dimensions of length and width. A shallow bath will give rapid working, but at the sacrifice of much burnt metal, or an excessive lowness of yield over metal charged. A deep bath will retard the melting and present difficulties in maintaining desirable thermal conditions. The medium will be learned by the individuality of the furnace and conditions of practice, but to put the problem in figures, the ranges for the choice will be between 15 inches to 20 inches of depth.

An important consideration in furnace practice is regenerator chamber volumes. The fuel efficiency will be controlled largely by the length of furnace as mentioned, and also upon the proper construction of the chambers. The purposes of them will be subsequently considered. At present attention will be given to their volumes. In that particular there will be conditions to take into account as to how much room can be allowed by the space in the building where the furnace or furnaces may be located both above and below the charging floor and the depth to which the foundations and flues can be safely carried. The efficiency of a regenerator chamber depends upon the number of " checkers " it can carry and the direction of incoming and outgoing gaseous bodies. Direction is meant by the flow of gases, whether they be nearly horizontal or nearly vertical in travel.

In American practice the longest dimension of the chambers is horizontal, while in European practice some are built with greater depth than length. It would seem, in view of the natural tendency of heated gases to rise, that the latter plan is the better, but, as stated, how they shall be built depends upon variable conditions; however, with a given chamber volume, the efficiency varies with the depth. There is quite a range of figures as to volumes of regenerators per ton of capacity with different plants, varying from 65 cubic feet to 140. A good figure to work by is 90 cubic feet per ton, allowing one third for gas and two thirds for air chambers.

If the fuel should be oil or liquid or natural gas, the volume can be decreased materially, because such varieties of fuel are led directly in the body of the furnace instead of passing through the regenerators, thus offering a possibility of dispensing with the space occupied by regenerators commonly used as ducts for producer gas, but it is better that a furnace be built with an eye to suitability for producer fuel, because the supply of liquid fuel or natural gas is subject to possibilities of irregular deliveries, and a furnace built only for the latter fuels would cause some annoyance were they to be short. By the same token producers should always be installed as a safeguard, no matter what fuel may be regularly used. Thus there would be but little delay to put the producers for gas into service were liquid fuel or natural gas to fail.

The uses of regenerator chambers will next be considered. The purpose is to store in them heat carried over by waste gases produced by the fuel combustion in the furnace body, the heat being absorbed by a large number of No. 1 firebrick, piled in such a manner that the gases in their travel from the body of the furnace to the stack will have to pass through innumerable ducts or passages. Bricks piled in such a manner are called "checkers." The plan is to pile the bricks so that they will form rectangular passages of about 3 to $3\frac{1}{2}$ inches in width. The passages will run horizontally and also vertically. Sometimes they will be in a direct line in both directions: the length and width of the chambers or the bricks may be piled in such a way that the passages are zigzag or "staggered." Generally they are staggered in a vertical direction with straight passages horizontally.

The question of draught has to be considered, and with as many bricks as it may be possible to checker and with the greatest possible depth of chamber, the free working of the furnace will be augmented by straight passages in both directions. Indications as to heat absorption by checkers can be gauged by the temperature of the waste gases entering the stack with furnace at full working heat.

Pyrometrical observations by the writer show normal working conditions of stack gases to be an average of 500° C., with gases entering outgoing downtakes at 1400° C., and with air at atmospheric temperatures entering chambers and passing

through them in uptakes at 1000° C., will suggest the heat absorption and radiation of checkers.

To understand the principle of regeneration it will be clearer in view of the fact that the temperature of flame combustion is not sufficiently high to maintain a continued liquation of a bath of molten metal as its carbon decreases, because the air necessary to support combustion, even with a forced draught, carries away or absorbs the calorific energy of the flame playing upon the bath of metal. In other words, cold air lessens the full heating value of flame combustion that should otherwise be spent in work. If, then, the temperature of the necessary air for complete combustion be raised, to that extent will the flame efficiency be increased. On that rests the principle of regeneration.

Let the course of the air be followed in the chambers of an open-hearth furnace passing from left to right. The reversing valves are in position to direct the inflow of gas and air in their respective chambers on the left side of the furnace. Passing through the checkers and innumerable ducts, they enter the uptakes. The gas upon reaching the furnace body immediately ignites and draws upon the accompanying air for complete combustion, the respective volumes of each being under control by the operator. The flame energy being dissipated in work, the waste gases are now drawn by the draught and pushed along by a rear expansion towards the stack, but, before reaching it, nearly their entire heat units are absorbed by the checkers in the right-hand set of chambers. After an interval of 15 to 30 minutes, the reversing valves are thrown and the gases are reversed in direction. The air and gas now passing into the already heated right-hand chambers carry back by radiation to the furnace body some of the waste heat previously deposited there to add to heat units produced by flame combustion. The efficiency of the flame will be greater from the right-hand chambers' work, assuming both sets to be of an equal temperature at the beginning of the operation, and after the second reversal, the left-hand chamber will bring a still greater increment of heat value than its neighbor. That is to say, the heat units radiated to the incoming air and increasing the flame value, necessarily permit more heat for the outgoing checkers to absorb. Thus it will be seen that with the increase in the number of reversals there will also be a gain in heat for work.

It would be possible to melt the best refractories by reaching high ranges of temperature by the principle of regeneration, but by careful watching on the part of the operator, flame and air volumes are properly regulated to prevent burning of the furnace. At the same time, enough heat must be maintained during the progress of a melt to preserve the fluidity and proper temperature of a bath of steel at proper intervals. Without the system of regeneration, it would not be possible to successfully handle 200 tons or less of liquid steel at a time in a single operation of an open-hearth furnace.

The speed at which the gases travel through the furnace when working is due to both draught and expansion. As soon as the cold incoming air comes in contact with the heated checkers, it immediately expands and produces a slight pressure which forces the body of air before it upwardly, and entering the furnace body not only assists the combustion of the fuel, but washes and protects, so to speak, the roof of the furnace with a film of air, and at the same time depresses the flame upon the bath of metal. With free passages in the downtakes and checkers, the stack will readily take care of the waste gases. Obstructions in either would make a slow working furnace and disagreeable waste of flame out of the furnace doors.

Another important feature about regeneration chambers is that they should never be under the furnace body or have their uptakes directly below the ports. In the first instance, there would be danger of irregular settling, causing cracks in the partition walls between the air and gas chambers, which would allow gas leakages and ignition of same before entering the furnace. In the second place, there is always more or less dust and slag carried along by the draught, which would be deposited in the checkers with chambers located as just mentioned, thus choking them, and, of course, cripple their life. Good practice requires that the chambers be placed at the furnace ends and extend at right angles to them under the charging floor. There should also be spacious receptacles at the lowest point of each downtake to retain accumulations of dust and slag before they could reach the chambers. Such are known as slag pockets, and with proper construction, they can readily be cleaned out without disturbing the checkers.

PROGRESS IN IRON AND IN MECHANICAL ART *

By J. H. WICKSTEED

USE OF THERMIT IN WELDING RAILS

A NEW departure is being followed before our doors in Leeds of joining tram rails by fusing the ends together with "thermit," and so making the rail one continuous bar for several miles of length. The object of the plan is that there shall be no gap between the ends of the rails, and no lost motion by vertical movement between the rail ends. When the rails are welded together, any deflection of the end of one rail caused by the weight of the rolling stock equally deflects the end of the oncoming rail and the rolling stock goes over a level surface The effect of this is to prevent the rail ends wearing down before the rest of the rail.

A similar system was tried some years ago in America by electrically welding the rails together or fusing them together with molten metal, but was not found altogether successful owing greatly to the stronger tendency of the rails to expand under the hot sun of the American summer, and to lift up from their bed. The experiment in Leeds was a bold one, in view of the expansion and contraction of steel between the extremes of temperature in England, but it has now been carried beyond the experimental stage, and it is proved that if the rails are sufficiently well anchored down to their concrete bed the power of the sun's heat upon their exposed surface can be so counteracted by end pressure that it has no effect in lengthening the rail. The rail is free to increase its volume in cross section sufficiently to absorb the summer heat without lengthening; in other words, it may expand and contract in the dimensions of depth and width, but can be mechanically restrained from expansion or contraction in the dimension of length. The improved arrangements for restraining the rails from bowing either sideways or upwards, and the success of the thermit welding, as now put in practice both at Leeds and at Coventry, has led to its introduction even in the hot climate of Ceylon.

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* Extracts from a lecture delivered at Leeds, November 16, 1905, before the Association of Yorkshire Students (Institution of Civil Engineers).

The Harmet Process for Casting Ingots

Any members who have followed the proceedings of the Iron and Steel Institute will remember a paper, given by M. Harmet, of Saint Etienne, on " The Compression of Steel during Solidification in the Ingot Mold, to avoid the Effects due to Free Shrinkage." The process is easily explained. The ingot mold has a movable bottom, which is pushed up as fast as the molten ingot contracts in cooling. Thus the sides of the ingot are pressed against the tapering sides of the mold, and are thereby squeezed inwards, which prevents the ingot from forming cavities in the center through contraction, and which also, by more rapid cooling, prevents the liquation of carbon in the fluid metal.

Although this paper was only read three years ago, the invention has been taken up both in Leeds, in Sheffield and in Glasgow.

The process seems to be akin to Sir Joseph Whitworth's invention, which he applied particularly to tubular ingots from which to forge hollow shafts, gun tubes, cylinder linings, etc. Sir Joseph Whitworth read a paper explaining his process, in 1875, before the Institution of Mechanical Engineers' meeting in Manchester, and the writer well remembers listening to that paper and the discussion which followed, in which Sir Wm. Siemens, Mr. John Ramsbottom and Mr. Daniel Adamson took a leading part. Sir Joseph Whitworth lined his ingot molds with sand, behind which there were grooves in the construction of the molding-box in order that all gas might escape from the molten metal. The pressure was raised to six tons to the inch. The process was entirely successful for his purpose. He even applied a pressure of 20 tons per inch, and found that with that amount of pressure the fluid-compressed steel was rendered so perfect that it could not afterwards be improved by any process whatever, and needed no forging for any purpose.

In the Harmet process there is no refractory lining, but the ingot is brought into immediate contact with the metal of the molding box. There is no pressure upon the ingot, but the solidifying portion and the spongy portion is squeezed inwards, as in wire drawing, so as to allow no cavity whatever for gases, or for vacuum through contraction, between the solidifying shell and the fluid center of the ingot.

The writer's firm have made a lathe spindle from steel cast by this process and afterwards forged and oil-hardened for a large lathe. This spindle was 27 inches diameter over the collars and 10 feet long, and carried a load of about 50 tons on the front neck.

Concurrently with this improvement in the casting of steel ingots, great improvements have been made, not only in the chemical composition of the steel itself, but also in its thermal treatment, after it has been forged into the article required. A $6\frac{1}{2}$-inch thick armor plate of to-day is as strong to resist the attack of a projectile as was armor plate 15 inches thick, when it was made of unalloyed iron.

HIGH-SPEED STEEL AND ITS USES

None of these improvements are more wonderful than those by which steel for cutting tools has been made, so that it will actually preserve a cutting edge hard enough to take heavy cuttings off ordinary steel and iron when it has become almost red hot. The consequence is that the speed at which machine tools, such as lathes, planing machines and drilling machines, can be worked is quite doubled. This has only been accomplished in the present century. Before the year of the Paris Exhibition in 1900, it was thought good work to drill a 1-inch diameter hole through a 1-inch thick steel plate in one minute. It is now just as practicable to drill the same sized hole through 2-inch thick in one minute. It is, however, done at the expense of heat. The reason it can be done is because the new steel keeps a hard edge at a temperature which would have softened former steels. It is wonderful to see a tool glowing with a dull red color turning off heavy cuttings blue hot from a steel forging at the rate of 60 feet cutting speed per minute, the cutting being $\frac{1}{2}$ inch deep and $\frac{1}{4}$ inch thick, and this to go on for six hours without relieving the tool. Still more wonderful feats can be performed with this steel for short runs, a 1-inch diameter hole can be drilled through 12 inches of cast iron in one minute; but there is an objection to developing too much heat in any hole which requires to be very smooth and true as the drill leaves it, and for this and other reasons it is enough to say that the improved steel will cut at double the speed that could be used up to the end of the nineteenth century.

In the nineteenth century 20 feet a minute was regarded as a good standard rate of cutting for a planing machine. To-day 40 feet a minute may be considered the standard. If planing machines cut on both strokes, doubling the speed of cut would double the work done in a given time; but if the machine has an idle return stroke, it is necessary to double the speed of the idle return stroke as well as that of the cutting stroke in order to attain a 2 to 1 improvement. A 3 to 1 ratio of quick return was considered good when the cutting stroke was at 20 feet, and this gave a return speed of 60 feet. To make a 2 to 1 improvement you must not only double the cutting speed, but you must preserve the ratio of 3 to 1, which doubles also the idle return speed and brings it to 120 feet per minute.

There is no difficulty in accomplishing this with a sufficiently powerful drive, and the high initial speed of electric motors facilitates obtaining sufficient belt velocity to give a quick return speed satisfactorily. The time lost in an idle return stroke of a planing machine, however, can be saved by making it cut on both strokes. This was recognized by Sir Joseph Whitworth before any of us were born, and he devised a semi-revolving tool holder which presented the cutting face in one direction for the inward stroke of the table, and, turning half round automatically at the reversal of the machine, presented the same cutting face to the outward stroke of the table, and thus saved all lost time during the working of the machine. The principle has been adopted by many makers of plate edge planing machines for planing ships' plates, boiler plates and girder plates. The work, however, for which this form of double cutting is most suitable is only plane surfaces, as it is necessary that the work should give room for the tool to turn right-about-face at each end of the cut.

When the work is of such a shape as not to give space for the tool to turn round, the drawback to this holder is that it is not adapted for cutting on one stroke only, because it does not relieve itself, and, being rigidly held, would lose its edge on the return stroke if cutting in one direction only. Many inventors since Sir Joseph Whitworth have attempted to design double-cutting tool boxes more adapted for general use, but probably the most successful system developed during the nineteenth century was that of having two complete sets of

tool boxes on independent cross slides and uprights constructed to face each other, and thus hold tools in self-relieving tool boxes, facing the work in opposite directions. This plan has been applied for planing the faces of armor plates where each cross slide has carried as many as eleven cutting tools, and this makes a highly efficient machine for such a special purpose.

The writer presented a paper to the Leeds University Engineering Society some years ago, in which he reviewed all the then-existing methods of cutting on both strokes, including a design of his own. In analyzing the advantages of all the designs and assigning marks of merit to them, with 12 for the maximum, he could not at that time credit any of these boxes with more than 11 marks. The full marks were four, under each of the following heads: Self relief, facility of adjustment, accessibility. But the double-cutting tool box which he has perfected since that date has all the convenience and stability of construction of a good single-cutting tool box, and gives the advantages of double cutting, when required, as well.

When single cutting is necessary, this tool box is just as convenient as an ordinary single-cutting box, and, under his former system of judgment, would obtain the full possible number of marks. It is, however, obvious that in some cases, as, for example, in planing valve faces inside a steam chest, there is only room for a single tool to enter the chest and start from a landing at one side of the valve seats, whilst it finishes at a landing on the other side, and in such a case one tool only can be used.

It needs no more than stating that in all work that is clear of projections close up to the planed part, the saving of time in a double-cutting machine is 25 per cent on the time taken for the same work on a machine with a quick idle stroke, having a speed ratio of 3 to 1 on the cutting stroke; but it should be explained that if a machine with an equal return stroke is working for only half its time double cutting, and half its time single cutting, it will still do as much work as a 3 to 1 quick-return machine which is single cutting through. Suppose you have such a quick-return machine working for 120 hours. It will be cutting for 90 hours, and returning idle for 30 hours. It will do 90 units of work in 120 units of time; but so will a machine with equal return stroke, if two thirds of the work

permits of double cutting, and one third has to be cut with a single tool. For if this equal-return machine be working for 120 hours, and cutting half its time on both strokes and half its time on one stroke only, then in the first half it will be cutting for 60 hours, and in the second half cutting for 30 hours and idling for 30 hours, and it, like the quick-return machine, will do 90 units of work in 120 units of time. Thus it is equal in output to the quick-return machine, if it works half its time double cutting, and it begins to gain upon the quick-return machine as soon as it is employed for a larger fraction than half in double cutting, and when it has reached full time double cutting it has gained 25 per cent.

It will be a revelation to many to see from this simple arithmetic that it is no bar to the advantages of double cutting on a planing machine that there may be many jobs which do not permit of the use of both the tools. On the contrary, the statement which you have just followed will make it clear to you, once for all, that even if one third of your work is better planed with one tool, you only lose the same amount of time by foregoing the quick return in doing that portion of the work without a quick return as you gain by double cutting on the other two thirds of the work.

CARGO SAMPLING AND ANALYSIS OF IRON ORE *

By W. J. RATTLE AND SON

BEFORE the installation of the "clam-shell," the sampling of boats was not such a difficult proposition; at that time boats were unloaded by shoveling the ore into buckets, the shovelers working down through the ore in the center of each hatch, to the floor, and then working out; this naturally gave good faces of ore to sample. With the slowness of unloading, the sampler found better walls of ore to sample and could take more time.

The present method of unloading varies, and consequently the method of procuring samples varies accordingly. For example, at the Erie docks, Cleveland, where they have three clam-shells, the boats are cleaned out until bottom is reached in all hatches; then the boat is shifted to the Brown bucket machines, and unloading is finished by hand. In this case, we aim to sample the ore when the boat has left the clams.

Sampling at Lake Erie Ports. — By the term "Lake Erie Ports" we mean all the docks from Detroit, Mich., to Tonawanda, N. Y. Our method of sampling is the same at all docks along the frontage defined above. The necessary tools used in sampling are a large-sized trowel, a hammer and a wide-mouthed can with a capacity of 45 pounds. With these the sampler enters the boat when bottom is reached, sampling every hatch in the following manner: Starting from one side, he goes around the walls from bottom to top, taking one half a trowelful of ore from every 18 inches, the distance between his perpendicular sampling being 24 inches. When lump ore is encountered, he takes a piece in bulk equal to the amount of fine ore taken on each trowel sample.

When he has filled his can, he dumps this upon a clean floor space in the boat, and proceeds until each hatch has been sampled. After completing this, he goes over his sample carefully, cracking up the lumps so that the entire sample can be homogeneously mixed together.

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* Abstract of a paper presented at the Lake Superior Mining Institute, Menominee Range, October, 1905. "The Chemical Engineer," December, 1905.

Our method of mixing the sample on the boat is by shoveling the ore from one pile to another, putting each shovelful on top of the cone until all the ore has been delivered from one pile to the other. After repeating this several times, the pile is flattened out by placing one corner of the cutting edge of the shovel in the top of the cone and circling the pile. This distributes the ore evenly and at the same time flattens the cone. The flattened pile is evenly quartered, and opposite quarters are thrown out. The above mixing process is continued and, if found necessary, the lump ore is crushed finer (this is done when 35 per cent or over of the cargo is lump ore); the last quartering (about 100 pounds) is saved and put into cans.

The amount of ore taken for each sample, before mixing and quartering, depends upon the tonnage sampled; this varies, but, as a rule, 45 pounds to 55 pounds is taken from each hatch. The last two opposite quarters are taken to our crushing-and-drying house on the docks, weighed and dried at 212 degrees; it is again weighed when dry and the difference is the cargo moisture.

The sample is then crushed in a Gates crusher, thoroughly mixed as described above; 10 to 15 pounds is sent by express to our laboratory for analysis, the sampler keeping in reserve one half of the last quartering for emergency.

The advantage of having these drying-and-crushing plants on the docks is that a larger sample can be mixed in the dried-and-crushed state, better than the wet ore as it comes from the boat. Also determining the moisture at the docks avoids all accidents that might happen to an undried sample in shipment, and gives the proper percentage of moisture in each cargo on its arrival at the unloading dock.

We believe firmly in large samples, 300 to 1,500 pounds. Of course the amount depends upon the tonnage sampled, but roughly $\frac{1}{4}$ pound per ton; this gives a sample that is representative.

Before the docks installed the present fast unloading machines, we used to take three rounds for each sample (sampling the ore in the boats when one quarter unloaded, again when one half out, and a third time when three fourths out), mixing all three samples together for our final sample; but now the time allotted to unloading is so short that three rounds are entirely out of the question. We have proven that one

large sample, taken when the boat is about one half out, gives the proper composition of the ore.

Laboratory Analysis. — The samples, having been dried at the docks, are run through a crusher until the ore will pass a 15-mesh sieve. After crushing, the sample is mixed and quartered to about 5 ounces. This is placed on a chrome-steel plate and bucked down until it passes a 100-mesh sieve; it is then thoroughly mixed by rolling. About 1 ounce of this ore is dried in a water bath at 212° F., placed in a bottle, corked tightly, and allowed to cool. From this dried sample, all determinations are made.

Iron. — Weigh ½ gram of ore into a No. o beaker; dissolve in hydrochloric acid, with the addition of a small amount of stannous chloride; reduce with stannous chloride while hot; transfer to a No. 4 beaker; add 10 to 15 cc. mercuric chloride and dilute to 400 cc.; add 10 to 15 cc. manganese sulphate mixture and titrate with permanganate. Mercuric chloride is in a saturated solution; manganese sulphate mixture is made as follows: Dissolve 800 grams in 5,550 cc. water; add 1,650 cc. phosphoric acid and 1,600 cc. sulphuric acid. Permanganate is made to have 1 cc. equal 1 per cent, using ½ gram of ore.

Phosphorus. — Dissolve 4 grams of ore in hydrochloric acid; evaporate to 5 or 10 cc.; add 40 cc. nitric acid concentrated; evaporate to about 15 cc., dilute and filter; add ammonia until it sets to a stiff jelly; then add a few cubic centimeters in excess. Redissolve with nitric acid, heat to 85° C., and precipitate with molybdate solution, made as follows: Dissolve 400 grams molybdic acid in 1,600 cc. ammonia (.96 sp. gr.) and add this to 6,000 cc. nitric acid (1.20 sp. gr.). Add 40 cc. of this solution and shake five minutes; settle, filter, wash with a solution of ammonium sulphate (25 grams of the crystals, 50 cc. sulphuric acid, 2,500 cc. water). Dissolve, precipitate in flask with ammonia (1 part ammonia, 3 of water); wash, filter twice with water; add 10 grams "mossy zinc," and 80 cc. sulphuric acid (1 part acid, 3 parts water); heat 15 minutes; filter through cotton, wash with water and titrate with permanganate, using the same solution as that used for iron determination (1 cc. equals 1 per cent iron on ½ gram of ore). Multiply number of cubic centimeters used by 0.2035; the result is phosphorus.

In ores which retain some of the phosphorus in the residue,

this is ignited over the blast for about five minutes in a crucible; then transferred to a beaker and boiled with 10 cc. nitric acid (1.20 sp. gr.) for 5 minutes and filtered into the main solution.

Silica. — Weigh out 1 gram of ore; dissolve in hydrochloric acid, add a few drops of nitric acid and evaporate to dryness; take up in hydrochloric acid and filter. Burn off the filter in a platinum crucible and fuse with carbonate of soda. Dissolve in weak hydrochloric and evaporate to dryness. Moisten with hydrochloric acid; add hot water; filter, wash with hot water and weak hydrochloric acid; ignite in crucible and weigh as silica.

Manganese. — Dissolve ½ to 2 grams of ore in hydrochloric acid; add 5 to 10 cc. sulphuric acid and evaporate until fuming freely; cool, dissolve in water, transfer to ½-liter flask; precipitate iron with zinc oxide suspended in water, dilute to mark and filter; measure off 2 portions of 200 cc. each and titrate each portion. Multiply number of cubic centimeters used by 0.1473 and divide by the number of grams represented in solution. The result is manganese.

Alumina. — Dissolve 1 gram ore in hydrochloric acid; evaporate to dryness, take up in hydrochloric acid, filter and fuse residue; dissolve the fusion in weak hydrochloric acid, evaporate to dryness; moisten with hydrochloric, dissolve in hot water, filter into first filtrate, neutralize with ammonia, add 3 and 3–10 cc. hydrochloric acid; dilute to 450 cc.; add 2 grams sodium phosphate in solution and stir until solution is clear; add 10 grams hyposulphite of soda and 15 cc. acetic acid (30 per cent); let stand 15 minutes, boil 15 minutes, filter, wash with hot water, dry, ignite and weigh as aluminum phosphate.

Lime and Magnesia. — Dissolve 1 gram of ore in hydrochloric acid and evaporate to dryness; redissolve in hydrochloric acid, dilute, filter and fuse residue with sodium carbonate; dissolve in weak hydrochloric acid, evaporate to dryness; cool, moisten with hydrochloric acid, dissolve with water, filter and wash into the first filtrate; heat to boiling, precipitate iron with ammonia, filtering while hot; wash several times with hot water, add a few cubic centimeters of ammonia to filtrate and heat to boiling; add 10 cc. hot ammonium oxalate, boil 5 minutes, let settle, filter and wash with hot water. After thoroughly washing beaker and precipitate, transfer precipitate

to the beaker in which precipitation was made; wash the filter with weak sulphuric acid; then add 15 cc. concentrated sulphuric acid, heat to 70° C. and titrate with the permanganate used for iron determination (1 cc. equals 0.005 grams iron). Multiply the result by 0.2500; the result is calcium oxide.

Magnesia. — Cool the filtrate from lime; add 10 cc. concentrated solution of sodium phosphate and ammonia (equal to about 1–10 the bulk of solution); stir well; let stand in a cool place over night; filter, wash with 10 per cent ammonia, ignite in porcelain crucible and weigh. Multiply the weight by 0.36036; the result is magnesia.

Sulphur. — Dissolve 3 grams of ore in aqua regia; evaporate to dryness, take up in hydrochloric acid and evaporate a second time; take up in hydrochloric acid again and filter. Precipitate with barium chloride while hot; let settle and filter; wash with cold water and weak hydrochloric acid; ignite and weigh as barium sulphate. It is always best to test acids; if sulphur is found, determine amount and deduct from results.

Loss by Ignition. — Weigh 1 gram of ore in platinum crucible; heat over blast lamp about 5 minutes; cool and weigh; the difference is organic and volatile matter.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

TESTS of High-Speed Steels on Cast Iron. L. P. Breckenridge and H. B. Dirks. "University of Illinois Bulletin," November 15, 1905. 10,000 w., many tables and illustrations.— The authors report the results of some experiments which have been in progress for nearly a year in the shop of the College of Engineering at the University of Illinois and conducted by Mr. H. B. Dirks, assistant in mechanical technology. The brands of steel used in the experiments were as follows:

1. Styrian marked " Bohler Rapid." 2. Jessop's " Ark." 3. McInnes's " Extra." 4. Mushet's " Special." 5. " Air Novo." 6. " Rex." 7. " Poldi." 8. " A and W " (Armstrong and Whitworth).

In shaping the tools they were given a front clearance of $12\frac{1}{2}$ degrees, a top rake of 10 degrees and a side rake also of 10 degrees, and these angles were carefully maintained throughout the tests. Directions for forging and hardening the various steels used were furnished by the manufacturers. Most of the steels were to be hardened in an air blast. The " A and W " steel was the only one in which oil was recommended for cooling, and then only after the cutting edge of the tool had been cooled to a cherry-red in the air blast.

In order that the results of the tests might be of general application, it was advisable that the cast-iron test pieces be the product of several commercial foundries. Several manufacturers

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus " A " denotes 20 cents, " B " 40 cents, " C " 60 cents, " D " 80 cents, " E " $1.00, " F " $1.20, " G " $1.60, and " H " $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

throughout the state agreed to furnish sample test pieces representing the grade of cast iron used in their respective foundries. A standard size of test piece was therefore decided upon, and blue prints and patterns of it sent to the different manufacturers. This test piece was made hollow for several reasons. A solid test piece becomes soft toward the center and is more likely to contain blow holes. Test pieces of small diameter become springy and consequently produce inaccuracies in the results. The high angular velocity necessary with small diameters is also undesirable.

A comparative hardness test was made on all samples, comparison being made with a standard piece of soft cast iron of equal density throughout. The hardness of cast iron or any other metal as indicated by a drill test is probably as fair an indication of the particular quality of the metal that affects the cutting speed as is obtainable by any process in use at the present time. This hardness test is, in itself, a cutting-speed test in which the cutting speed is not varied, but is held constant and the rate of feed allowed to vary, the cutting speed and rate of feed in all probability bearing some constant relation to each other. The tests were made with a drill press. A constant load of 312 pounds was applied on the spindle of the drill press by means of the weighted lever. With the spindle rotating at a constant speed of 87 revolutions per minute, the rate of feed of the drill in inches per minute was measured, readings being taken for every ⅛ inch of depth drilled. The drill used in these tests was a Morse standard ½-inch twist drill ground to an angle of 62½ degrees. As, however, there was some liability of variation in the sharpness of the drill, thus affecting its rate of feed, a uniform piece of cast iron was first drilled into, readings taken and then the test made on the test piece. A comparison was thus always made with this same piece of cast iron, eliminating any small variation in the sharpness of the drill.

The apparatus used in conducting the tests consisted mainly of a high-speed lathe deriving its power from a two-phase induction motor by means of belting and a countershaft, the power required being measured by a polyphase wattmeter.

The effort exerted by the tool in cutting was determined and the horse-power lost in driving the lathe and countershaft was deducted from the total horse-power used during the trial, the

difference being the net horse-power required for cutting. This was reduced to foot-pounds per minute, and divided by the cutting speed, giving the force exerted. The figures so obtained
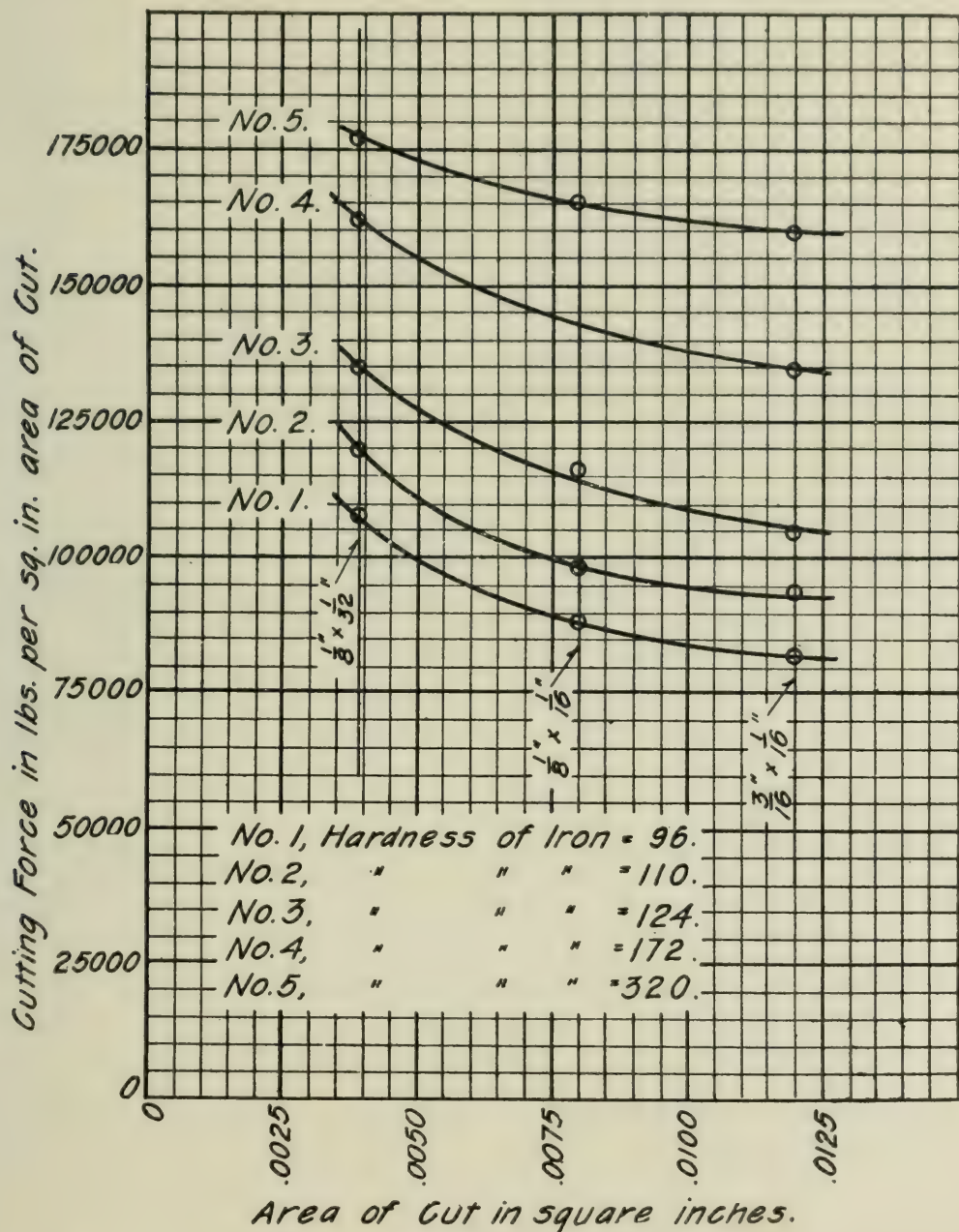
FIG. 1. Curves showing Relation between Cutting Force on Point of Tool and Area of Cut for Cast Iron of Varying Hardness.

were reduced to pounds per unit area of cut, and plotted as ordinates upon a base of area of cut in Fig. 1. The curves show

that the cutting force was not directly proportional to the area of cut, but decreased as the area increased, and that the average
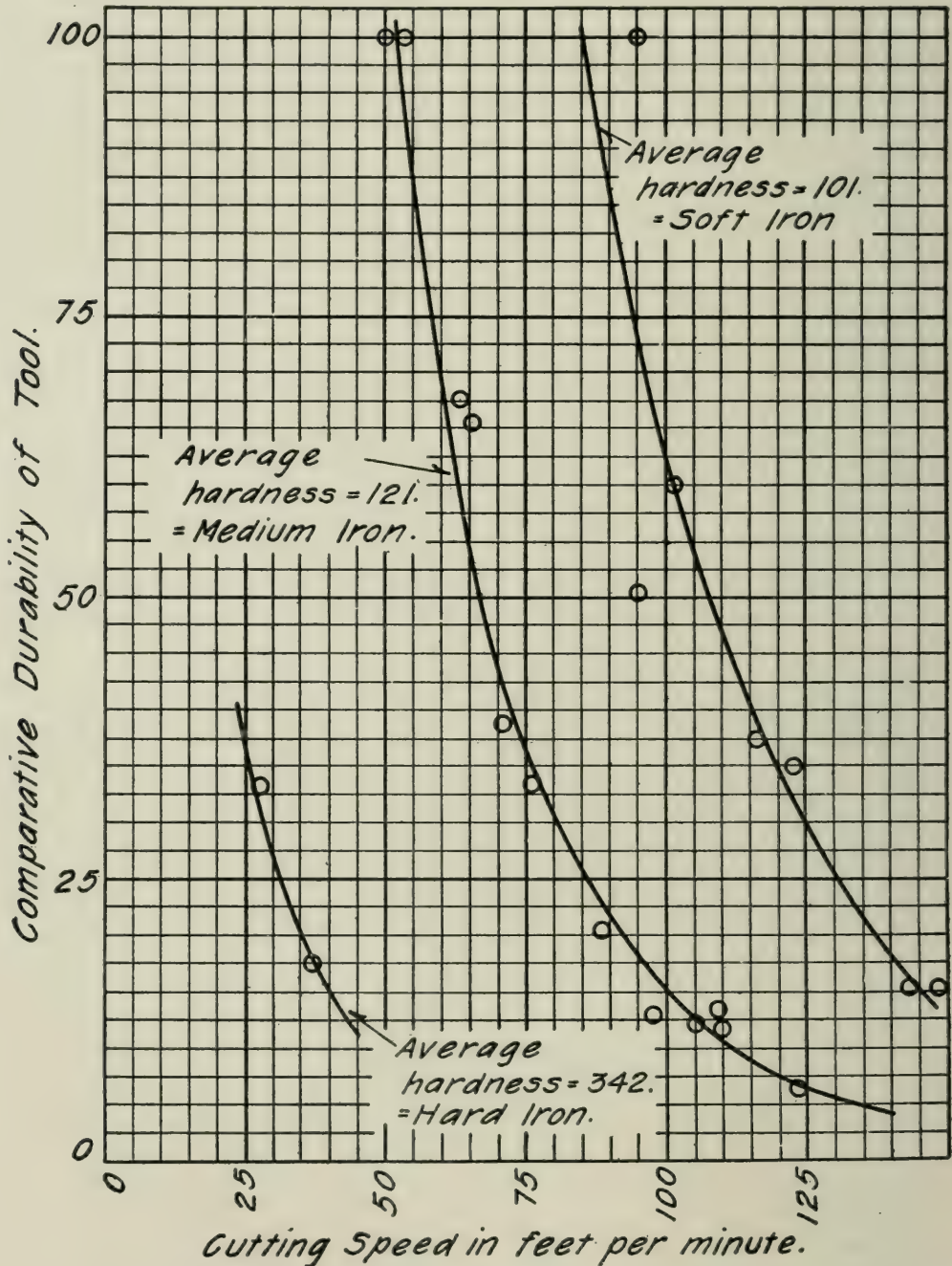
FIG. 2. Curves showing Variation of Durability of Tool-Cutting Speed for Cast Iron of Varying Hardness; Average of all Tool Steels.

cutting force varied from 50 tons per square inch for soft cast iron to 85 tons per square inch for hard cast iron. Each curve

shown in the figure represents a different hardness of cast iron. The relative hardness is shown in the table on the figure.

In Fig. 2 are shown the curves which represent the relation

Curve showing variation of
Cutting Speed with Hardness
of Cast Iron, with results of
all tool steels.
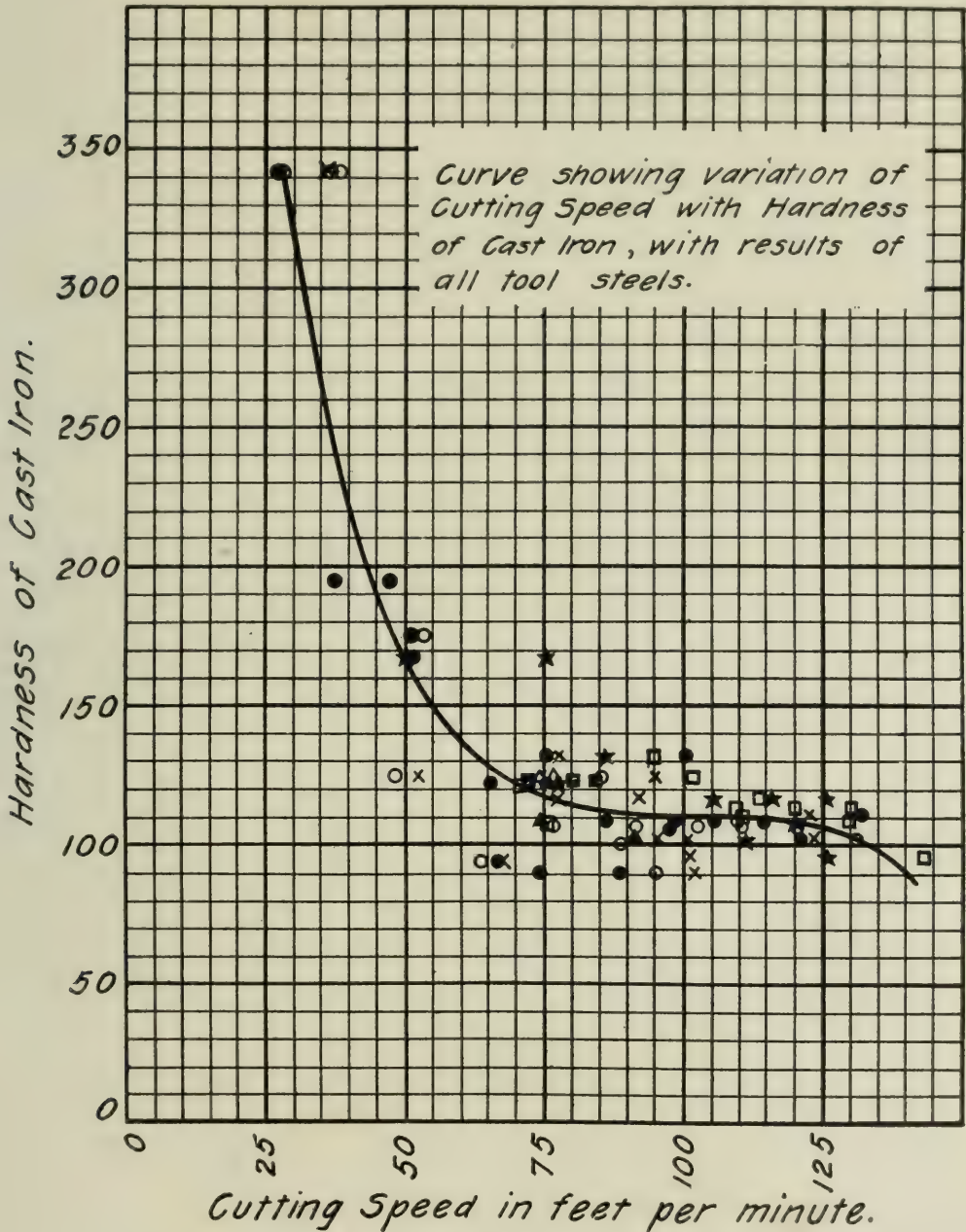
FIG. 3. Curve showing Cutting Speeds it is Advisable to use with a Variation in the Hardness of the Cast Iron.

between the durability of the tool and the cutting speed. These are important curves. Each curve represents a different hard-

ness of cast iron. Referring to the middle curve, which is for cast iron of medium hardness, it will be seen that a cutting speed of 50 feet per minute is satisfactory, the durability being 100. If the speed is increased very materially, the durability decreases quite rapidly. It is evident that for each hardness of cast iron, the cutting speed allowable for a maximum durability exists where the vertical line indicating cutting speed is tangent to curves similar to those drawn.

The curve shown in Fig. 3 represents the advisable cutting speed on cast iron of varying hardness. This curve represents the result of all the tests of the different steels tested. This curve shows: (*a*) that any of the steels tested can remove very hard cast iron at a rate of 25 feet per minute; (*b*) that all of the steels tested begin to wear rapidly at speeds a little above 125 feet per minute. Between these two points the relation between a safe cutting speed and the hardness of the cast iron seems to be definitely expressed by the curve. It would seem that cast iron of medium hardness, 100 to 120, could be cut at 125 feet per minute just as readily as at 70 feet per minute, as far as any injury to the tool is concerned. It must be remembered that this curve does not take into account the effect on the cutting speed of the variation in the area of cut; the experiments from which the curve was plotted were in all cases those in which the cut was very nearly $\frac{1}{8}$-inch in depth of cut by $\frac{1}{16}$-inch feed, so that there is but a slight variation in the area of cut in all of the experiments. From the curve of Fig. 3, we find the cutting speeds given in Table I to be applicable to the grades of iron manufactured by the different companies sending test pieces. In order that any company may make use of the curve shown in this figure, it will be necessary simply to determine the average hardness of its cast iron, as explained elsewhere, and where the horizontal line representing this hardness cuts the curve, the possible safe cutting speed may be read on the scale below. This curve should prove useful to various manufacturers.

TABLE I

ALLOWABLE CUTTING SPEEDS FOR GRADES OF CAST IRON
USED IN THE TESTS

Name of Company sending Test Pieces		Average Hardness of Test Pieces	Allowable Cutting Speed
American Radiator Co., Chicago, Ill.	Pierce Plant	101.8	132.0
	Michigan Plant	110.7	118.0
	Detroit Plant	109.3	120.0
	——— Plant Marked " 5–17–05 "	112.7	90.0
	——— Plant Marked B " 5–26–05 "	138.1	60.0
	——— Plant Marked B " 6–2–05 "	103.1	132.0
Crane Company Chicago, Ill.	Gray Iron	132.0	63.0
	Ferro-Steel	342.0	28.0
Root, Van Dervoort Eng'g Co. East Moline, Ill.		175.2	48.0
University of Illinois M. E. Dept. Shops.		136.3	60.0

Generally speaking, all the steels tested proved equally effective. It is very evident that there are great possibilities ahead for high-speed steels. Before realizing their full benefit, however, certain advances must be made. Heavier machine tools must be built. The capacity of the motors and power plants must be increased. Special hardening furnaces with temperature-measuring devices must be available. More must be known concerning the chemical and physical properties of the various steels.

Tool steels are now available that will cut cast iron from two to three times as fast as was possible a few years ago. When every advantage has been taken of these possibilities, the cost of manufacturing many articles should be materially reduced. **No. 464.**

Fire Clays and Molding Sands. Percy Longmuir. Paper read before the British Foundrymen's Association. " Iron and Steel Trades Journal," January 12, 1906. 6,500 w. **No. 465.**

Equilibrium Diagram of the Iron-Carbon Alloys (Sur le Diagramme d'Equilibre des Alliages Fer-Carbone). George Charpy. " Comptes Rendus," December 4, 1905. 2,000 w.— The author discusses the meaning of the cooling curves of iron-carbon alloys. **No. 466.**

The Use of Molten Cast Iron in the Basic Open-Hearth Furnace (Ueber die Verarbeitung Flüssigen Roheisens im Basisch Zugestellten Martins ofen). C. Dichmann. " Stahl und Eisen," December 1, 1905.— The author discusses the advantages of charging molten cast iron into the basic open-hearth furnace. **No. 467.**

The Talbot Furnaces of the Jones and Laughlin Steel Company. " Iron Trade Review," February 8, 1906. 2,500 w., illustrated.— An illustrated description of a battery of five open-hearth tilting furnaces, each of 200 tons capacity. **No. 468 A.**

Determination of Carbon in Steel by Direct Ignition with Red Lead. Charles Morris Johnson. Proceedings Engineers' Society of Western Pennsylvania, January, 1906. 7,000 w. **No. 469 D.**

Power required to Thread, Twist and Split Wrought Iron and Mild Steel Pipe. T. N. Thompson. A paper read before the American Society of Heating and Ventilating Engineers. Abridged in " Iron Age," January 25, 1906. 3,500 w., illustrated. **No. 470 A.**

The Bertrand-Thiel Open-Hearth Steel Process (Le Procédé Bertrand-Thiel pour la Fabrication de l'Acier sur Sole). " Génie Civil," November 4, 1905. 2,500 w. — A description of the Bertrand-Thiel process as conducted at Kladno. **No. 471 D.**

METALLURGICAL NOTES AND COMMENTS

Alexander Lyman Holley   Alexander Lyman Holley* (see frontispiece) was born in 1832, in the small village of Lakeville, Conn., the son of a manufacturer of cutlery, at one time governor of the state. After obtaining his early education in the village school and in academies, he entered Brown University, in Providence, R. I., from which he graduated with honors in 1852. Holley then entered the employ of Corliss & Nightingale, devoting his attention to the building of an experimental locomotive which, however, proved a failure, and in later years in an after-dinner speech he referred to this locomotive as being a cross between Mephistopheles and a Colorado mule, having an inborn cussedness. A few years later Holley became the partner of Zerah Colburn, the proprietor of Colburn's " Railway Advocate," assuming the duties of the editor and in 1856 he became the sole editor and owner of that publication, and for several years devoted his efforts and energy to journalistic work. In 1857 Colburn and Holley made an extensive trip to Europe to study the European railway practice, and the results of their investigations were published in a large volume, soon followed by the appearance of another treatise, " Railway Practice in America," written by Holley alone. From 1858 to 1863 Holley was correspondent to the London *Times* on engineering topics, contributing to that paper over two hundred articles. In 1859 he made a second trip to Europe, and in 1860 a third one, dividing his writings between the *Times* and the " American Railway Review," of which he became mechanical editor.

He was sent to England in 1863 to investigate the Bessemer process for making steel. It had been tried in an experimental way by Cooper and Hewitt, but with them, as in England, the difficulties encountered had proven to be a serious setback to its introduction. Alexander Holley's keen observation recognized the inherent value of the process, and he secured for his clients the sole American license.

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* For the substance of this biographical sketch we are indebted to a recent publication entitled " Eminent Engineers," by Dwight Goddard.

He returned, was admitted to the firm of Griswold, Winslow & Holley, and began, in 1865, the construction of a Bessemer steel plant at Troy, N. Y. From this time on his energies were largely given up to the engineering problems of this process. In 1867 he designed and built the works at Harrisburg, Pa. Then, in 1868, he rebuilt the works at Troy.

In the years that followed he designed the works at North Chicago, Joliet and the Edgar Thompson works at Pittsburg. The latter he valued as his most conspicuous success.

Then the licensees formed themselves into an association of Bessemer steel manufacturers, of which Holley became the consulting engineer. In this capacity the works at St. Louis, Cambria, Bethlehem and Scranton were built. Holley, more than any one else, is to be credited with the marvelous practical and commercial success of this process. Mr. Robert W. Hunt, in speaking of Holley's pre-eminent services in enormously increasing the production and cheapening the cost by the high excellence of his general plans, credits him with the following particular improvements: Raised furnaces and converters, top supporters, hydraulic cranes, use of three ingot cranes, location of converter in relation to pit and furnaces, improved ladle crane, a single operating point for all cranes, ladles and converter; use of cupolas instead of reverberatory furnaces, an intermediate accumulating ladle placed on scales, an improved ladle bottom. These were not all that he contributed, but were the most radical and conspicuous. He received, in all, sixteen patents, ten of which refer to improvements in the Bessemer process, the last of which, made almost on his deathbed, was for a removable shell for the converter, to be used especially for the newly introduced basic lining.

While always loyal to the Bessemer process, his interest did not end there. He gave much thought also to the Siemens-Martin open-hearth process, and the furnaces of this style built with him as consulting engineer, were for some time the finest in the country. He believed in the Pernot furnace, the Thomas-Gilchrist patents and the basic lining, and had an influential part in their practical introduction.

In 1865 he was elected a trustee of Rensselaer Polytechnic Institute, and always after had a deep interest in technical education. In later years he delivered lectures on metallurgy and

engineering subjects before the Columbia School of Mines and Stevens' Institute. He was president of the Institute of Mining Engineers in 1875, a vice-president of the Civil Engineers in 1876, a founder of the American Society of Mechanical Engineers, a member of the British Institute of Civil Engineers, the Iron and Steel Institute and a recipient of the Bessemer gold medal.

He began life in perfect physical health, but his habit of intense and prolonged application told on him at last. As early as 1875, when only forty-three years of age, he began to feel the effects of the enormous strain. He was seriously ill in 1881, but recovered only to collapse again in 1882, from which he never rallied.

Unconsciously he pictured his own end one night at Pittsburg, when he had been called from a sick bed to respond to a gift of plate from his associates. What could be more beautiful and pathetic than his closing words on that occasion:

" Among us all who are working hard in our noble profession, and are keeping the fires of metallurgy aglow, such occasions as this should also kindle a flame of good-fellowship and affection which will burn to the end. Burn to the *end!* — perhaps some of us should think of that, who are ' burning the candle at both ends.' Ah, well! may it so happen to us that when at last this vital spark is oxydized, when this combustible has put on incombustion, when this living fire flutters thin and pale at the lips, some kindly hand may 'turn us down,' not ' under-blown,' — by all means not ' over-blown ' — some loving hand may turn us down, that we may, perhaps, be cast in a better mold."

Holley was a most prolific writer, and the number of important and, in many instances, masterly articles which he wrote would count up well in the hundreds.

Alexander Lyman Holley fairly won his place as the foremost and best beloved American engineer and metallurgist.

The Resistance of Materials to Shear.* — Among the various conditions of stress to which materials of engineering are subjected in construction and operation, that of shearing action has been given a smaller share of attention than its importance warrants. By far the greater number of tests of materials are made by subjecting the specimen to tension, while compression

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* " Engineering Magazine," February, 1906.

tests, torsion tests drop tests and other forms of trial have been largely employed. In many of the textbooks the resistance of a material to shear is based upon the resistance to tension, an arbitrary relation being given, without due attention to the obvious fact that this relation must differ for materials of different kinds. The importance of the study of shearing action is manifest when it is considered that it exists in nearly every case in combination with other stresses, and in some instances it may become the element of controlling importance as regards the safety of the structure under consideration. Thus in the case of a deflected beam, the upper portion may be under tension while the lower part is in compression, but manifestly the neutral plane, where tension ceases and compression begins, is under shear, the forces above and below acting in opposite directions. In like manner shear forms an important element among the stress existing in cases of torsion, and it is well known that the recent re-investigation of the distribution of shearing stresses in masonry dams has attracted much attention and created some little apprehension in connection with such structures. In a paper recently presented before the Institution of Mechanical Engineers, by Mr. E. G. Izod, there is given the results of some actual tests made to determine the behavior of materials under pure shear, and the results may be received as a welcome addition to a department of engineering in which the stock of information is none too complete.

The experiments of Mr. Izod were made in the engineering laboratory of University College, using a 100,000-pound Greenwood & Batley testing machine, with special clamps arranged so as to eliminate, as far as practicable, any bending of the test piece, and to insure the production of a pure shearing action. The tests were made upon pieces of rectangular section, and tensile tests were also made upon corresponding pieces of the same materials, the intention being to discover what relation, if any, existed between the resistances to shearing and to tensile stress. The tests included such materials as cast iron, wrought iron, steel and a variety of bronzes and brasses, the steels including mild steel plate and Swedish crucible steels with carbon content from 0.12 to 0.77 per cent, the results being tabulated and plotted in curves.

For the details of the tests, the reader must be referred to the original paper, but some of the interesting points brought out in the paper and in the discussion may be noted here. Apparently no positive relation exists between the shearing resistance and the tensile strength of a material.

" All the results obtained in the experiments seem to point to the fact that there is no common law connecting the ultimate shearing stress with the ultimate tensile stress, the ratio varying greatly with different materials. The test figures from the crystalline materials, such as cast iron or those with very little or no elongation, seem to indicate that the ultimate shear stress exceeds the ultimate tensile stress by as much as 20 or 25 per cent, while from the fibrous materials, or, more properly speaking, those with a fairly high measure of ductility, the ultimate shear stress may be anything from 0 to 50 per cent less than the ultimate tensile stress."

Thus, for wrought iron, the shearing strength appears to be about 75 per cent of the tensile resistance, while for cast iron the resistance to shear runs from 10 to 52 per cent above the tensile strength. The low-carbon steels show about the same ratio as wrought iron, while a crucible steel of 0.71 carbon has a shearing strength of 65 per cent of the tensile.

In comparing the ratio of shearing to tensile resistance with the elongation, a certain relation appears, there being a certain uniformity in the results. Thus, when the ratio of the shearing to the tensile resistance is close to 60 per cent, the elongation shows very little variation from 10 per cent. Below and above the 60 per cent ratio the elongation increases, that at the 50 per cent ratio being almost equal to that at 70 per cent, while from the 70 per cent ratio upwards the variation is inclined to be regular, the elongation decreasing as the ratio becomes higher, until with a very small or practically no elongation the ratio might be expected to become 120 per cent or 130 per cent; that is, that the ultimate shear would exceed the ultimate tensile stress by 20 or 30 per cent.

In the course of the discussion on Mr. Izod's paper some interesting points were brought out. Thus, Professor Lilly called attention to the fact that tests for ultimate strength were destructive tests, so that the load is not uniformly applied over the entire section, and that different results are obtained with

different depths of test piece. He also spoke of the fact that the shearing resistance bears a relation both to the tensile strength and the compressive strength of a material. In this respect it may be of interest to note the investigations of Professor Mörsch, in Switzerland, reviewed in the issue of this magazine for March, 1905. Although the investigations of Professor Mörsch related more especially to concrete, they included the general question of the relation of shearing stresses to tension and compression, and showed that in general, the resistance to shearing is found to be a mean proportional between the tensile and the compressive strength, so that the resistance to shearing may be taken as the square root of the product of the tensile and compressive resistance. Since Mr. Izod does not give the compressive resistances of his test pieces, it is not possible to apply this rule to his experiments, but it can well be seen that for materials with a proportionately high resistance to compression, such as cast iron, this would give a shearing resistance materially higher than the tensile strength, while for a material in which the compressive resistance is lower than the resistance to tension, the ratio would be lowered. An examination of the appearance of the ruptured sections of specimens divided by shearing will show that both the tensile and the compressive resistances of the material have been overcome, and hence it is but reasonable to expect that the shearing resistance should be a function of them both.

There is little doubt that resistance to shearing plays an important part in nearly every form of resistance to stress, and this is indicated by the fact that when rupture occurs it nearly always takes place in some other direction than that normal to the applied stress. Thus, in the case of yielding to tension, the test piece very rarely yields by breaking straight across, the break being in a diagonal direction, or with a conical fracture. When tubes are ruptured by internal pressure, the break is a diagonal one, unless, by reason of a weld, seam or other change in homogeneity the line of the break is otherwise localized. In every case there are undoubtedly a number of causes and effects operating together, and it is a distinct error to assume that one particular cause can be selected as producing an especial effect.

Such experiments as those of Mr. Izod are to be welcomed, but it is greatly to be desired that any such piece of work should

be undertaken with an entirely open mind, not with the pre-
conceived intention of finding out the relation, as in this case,
between the tensile and the shearing resistance, but in a spirit
of unbiased investigation of all the associated phenomena, so
that the true relations of all the elements involved may be deter-
mined. If, in connection with these valuable tests, there had
been associated a simultaneous set of tests of the tensile, com-
pressive, torsional and bending resistances, together with the
chemical and physical properties of the various specimens, and
the resulting mass of data had been critically examined to dis-
cover the nature of their relations, there is little doubt that a
different set of conclusions would have been reached. Inde-
pendent investigations are not to be discouraged in any case,
but it requires only an examination of such painstaking work
as that performed by Mr. Izod to render it evident that it is
only by a concerted attack upon the action of molecular forces
that the true nature of their action can be discovered.

The Lake Superior Iron-Ore Deposits.* — With the close of
the year 1905 there has come the usual review of the various
natural resources of the United States, and among these there is
none more impressive than that relating to the iron-ore supply
of the Lake Superior district. From this district the United
States Steel Corporation draws the greater part of its supply of
raw material, while upon the control of certain portions of these
ranges depends in great part the ore-carrying business of large
railway interests. In recent issues of the " Iron Age," the trade
of this district is discussed by Mr. Dwight E. Woodbridge, a
review being given of the output for the past year, together with
an indication of the developments.

During the year 1905 the shipments from the district
reached 34,000,000 tons, being more than 12,000,000 tons
greater than those of the preceding year, a gain of about 57 per
cent, or a gain of more than 60,000,000 gross tons in excess of
the greatest previous year. Of this enormous tonnage, more
than 20,000,000 came from the Mesaba range, the balance being
divided among the Menominee, Marquette, Gogebic, Vermilion
and Michipicoten ranges.

" The vast tonnage shipped in the past season was seemingly

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* " Engineering Magazine," February, 1906.

so easily moved and sent forward with so little friction that it is difficult to believe that in no year during the life of the Mesaba range had there been such obstacles to the free movement of ore from mines, nor had the mining companies and railroads ever worked under such difficulties and discouragements. As the Mesaba range furnished about 60 per cent of the total ore moved to lower lakes in 1905, any derangement there had an effect far more than ordinarily important and far-reaching. Time after time, during the entire summer, there were disastrous floods; the heavens seemed to open and pour out upon the heads of the struggling operators such rains as had never been known. Time after time were the open pit mines of the range — those very properties upon which the mining companies had depended for their great shipments — buried so deeply in lakes and rivers of water that even the booms of the steam shovels were invisible. For three months these floods succeeded each other with a disgusting regularity and frequency.

" Shipments for single railroad systems were extremely large. The Duluth, Mesaba & Northern, which serves mines upon a portion of the Mesaba range, handled to its docks in the month of July, 1,408,000 tons, or 50,000 tons per day, and averaged during the entire season of navigation better than 1,000,000 tons each 30-day period. The Duluth and Iron Range, serving the entire Vermilion and a portion of the Mesaba range, moved during the year a trifle below 1,000,000 tons per month, while the Chicago & Northwestern, with docks at Escanaba and Ashland, had a gross business at both points of about 6,000,000 tons. A departure in traffic conditions was made during the fall by the Wisconsin & Michigan Railway, which opened its ore line to points on the Menominee range, hauled ore from mines to docks at Peshtigo on Lake Michigan and transported it from there to furnaces at Chicago and elsewhere on modern car ferries, each capable of carrying a train of loaded cars. The innovation of utilizing ferries to move loaded trains, thus obviating ore piers and saving 280 miles of railroad, which was replaced in this company's scheme by the free highway of Lake Michigan, is an interesting method of long-distance transit. The car ferry, for crossing great lakes and for moderate distances, has long been in favor, but this is the first time any such system has been adopted in lieu of main-line

long-distance traffic, and the result will be watched with some interest."

In view of the rapid development which is being made in the district, it is interesting to observe that some of the independent interests are acquiring ore reserves, so that the whole region is by no means controlled by the steel corporation. Thus, the Hill interests, including those of the Great Northern Railway, hold a number of important leases, including the Mahoning mine, estimated to be capable of producing 1,000,000 tons a year for 60 to 75 years, but this and other mines classed as Hill holdings are really leaseholds, thus being valuable payers of royalties, and furnishing profitable hauling, but not open for disposal during the life of the leases.

" Exploration during 1905 has been more general than for some time. It has not been confined to the Mesaba, but has extended to the once-promising Vermilion, to the Menominee and to parts of the Marquette and Gogebic ranges. Deep shaft sinking on the last-named range is opening ore deposits that give the brightest promise for the future, a promise of maintaining the output of the district at a steady price for many years. Drilling on parts of the great ore-bearing formations of the Menominee range is opening a few mines of importance and is giving hope for more. Though immense sums have been spent in the Vermilion in past years with the diamond drill, no large deposits have ever been found aside from the Soudan and Ely groups. Now a number of drills are at work elsewhere. On the famous Section 30-63-11, where drill work had been carried on for three years, a shaft is now dropping slowly through the hard jasper and iron formation of that difficult region. At this prospect some ore has been found, and it is probable that the deposit may pan out as a very fortunate discovery.

" In what is known as the Austin, Swanzey and Palmer districts of the Marquette range, explorations during the year have revealed what may be of great importance. There are in these districts immense bodies of low-grade ores, highly silicious, some well within the Bessemer limit as to phosphorus and others highly in that element. Hundreds of millions of tons of fair ores are known to exist about Palmer, as well as in other parts of both the Marquette and Menominee ranges, which will be wanted in due time and are advantageously located as to freight charges."

Among the new districts in which developments may be expected, Mr. Woodbridge notes the Deerwood or Cuyuna range, about 100 miles west of Duluth, the Baraboo range and the Atikokan range, in western Ontario, while he states that steps have been taken for the immediate development of the Moose Mountain region, north of Georgian Bay, in Canada, where there are large deposits of magnetite.

" In preparation for the operations of 1905 as well as for 1906, an enormous quantity of dead work has been carried forward. On the Mesaba range alone, stripping contractors and mining companies have moved in 1905 above 6,000,000 cubic yards of overburden, one contracting firm alone removing more than 2,600,000 yards. On this range the evolution from underground to open pit, before referred to, has been general and with accelerated speed. It is now no bar to stripping that a mine is covered by 100 feet of overburden of bowlders, hardpan, drift or ledge. It is all rolled back and carried off, providing the ore deposit is of sufficient thickness to make the subsequent mine operations economical. Many a Mesaba mine which has been operated underground from the beginning is to be stripped; indeed, many have already been changed from one system to the other. The Oliver Iron Mining Company alone is buying this winter an additional stripping and mine equipment of 65 standard gage locomotives and 25 steam shovels, which is an indication of its plans for changing to open pit and mining by shovel. There will be, at the opening of 1906, not less than 120 heavy steam shovels working on this range."

With all this development in the iron ore trade, there naturally follows preparations to handle this enormous tonnage on the lakes. It has been estimated that for the five years ending with 1910 the average shipments may readily be 40,000,000 tons per year as against 25,000,000 tons for the preceding five years. This means that the 4,000- to 5,000-ton boat will be replaced by carriers of 10,000 to 12,000 tons, reaching 600 feet in length, and constructed with the combined experience of both the owners and lake shipbuilders.

The Handling of Tool Steel.* — When any number of tools are to be made I have found it a good practice to forge the tools

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* Arthur Stockall. From a paper read before the National Railroad Master Blacksmiths' Association. " The Iron Age," January 25, 1906.

first and let them get quite cold before tempering them. I work the steel at as low a heat as possible and as quickly as possible, but not with a heavy blow as is sometimes given by careless workmen under a steam hammer, as this destroys the grain by crushing it. Consequently, when the steel is tempered, it will develop what are called tempering cracks. It is better to forge the tools with a sledge or a belt hammer, such as a medium-sized Bradley hammer, as with these the tool can be shaped without injuring the texture of the steel. To temper the tool I beat it just hot enough to give it sufficient hardness, plunging it in a cooling mixture, gradually down to the upper end of the red, then pulling it out gradually. This will give a tapering from a low red at the upper end to a cold point, leaving the tool without any or with but very little contracting strain. Then I ease off the temper to the desired color, and, generally speaking, if the steel is of an ordinary good quality the tool will be good. This is our practice for lathe, planer and slotter tools, twist drills, reamers, rose bits and like tools made out of high-carbon steel. Miller cutters and such tools we forge the same way, but in tempering we use a small charcoal furnace, and lay our tools in the furnace on a good bed of fresh red coals; then we put more coal on top of them and close the door of the furnace, letting the cutters get hot as the coal burns up, while the tool dresser is at work on other tools. When the cutter becomes hot we plunge it into a tempering liquid slightly heated. To draw the temper we place a piece of ordinary plate iron on the bed of charcoal which is left in the furnace. The cutter is then placed on this plate until it is slowly heated throughout. It is surprising how nicely this method will draw the color.

High-Speed Tools

For high-speed tool making we have five different makes of steel, and they all have their own little peculiar differences of texture, consequently a little different way of working is necessary. These little points of difference have to be picked up by the tool maker. In forging a tool we generally follow the directions given us by the manufacturers of the steel, but in hardening the tool is where the difficulty lies, for I have found that this kind of steel deteriorates rapidly by tempering; that is, it gets soft in its texture as though some of its chemical

parts have lost their cohesion, after two or three times tempering. This is due, I think, to the high heat necessary for hardening by air blast. The point for us to discover is, how to harden this steel at a low heat and thus preserve its quality. I have tried the ordinary tempering mixture and also warm water. The steel will crack easily. With oil it is better, but not hard enough for hard tires, and ends like the air blast in a softer tool.

Tempering with Lower Heats

I am now experimenting with a liquid that certainly makes the tool hard enough at a greatly reduced heat. Whether it will keep its cutting power I am not prepared to say at present; but our practice is for lathes, planers and such machines, and where the speed is high and the material difficult to harden in an air blast at white sweating heat. For wheel-boring cutters I have an air blast made of copper pipe which straddles the tool. This is softened, to make it bend easily, so that it can be readily adjusted to suit any length of tool. I also have a pair of tongs with broad jaws, with which I grip the tool in the middle and put it in the fire and heat only both ends. I then place the cutters between the ends of the blast pipe and gradually turn on the air. This cools off both ends at once, leaving the center at its usual temper, and I must say that the tools made in this way work splendidly. For taps, reamers, twist drills, miller cutters and like tools that have to be finished to a cutting edge before tempering, I have used the lead bath for heating and cooling in air where convenient and in oil when necessary; but when air is used great care must be taken or the fine edge will be blown off. The lead bath, where only one or two pieces are to be tempered, is very slow and inconvenient. I have found the following plan very good in this kind of work. I mix some fireclay very thin, almost to a liquid; then I heat the tools just warm, not red, and dip them in the fireclay; then I pull them out and let them dry, which only takes a short time. Repeat this until you have a layer of clay on the tools sufficient to protect them from the heat of the fire or blast —one-sixteenth or one-eighth inch thick is plenty. Then place them in the fire and heat them to the desired point and cool them by a blast or in an oil bath.

The Steel Corporation.* — The United States Steel Corporation report for the last quarter of 1905 gives us approximately complete figures for the best year the corporation has had since its organization, with one exception. That was the boom year, 1902. In 1905 the first part of the year was comparatively quiet, and it was not until the second quarter was well advanced that the rising wave of prosperity began to be clearly visible. In our issue for January 16, the net earnings for the fourth quarter were estimated at $35,500,000. This was slightly above the actual result, the figures now given out being $35,278,688, which brings the total for the year up to $119,850,282. This was slightly below 1902, but it exceeded the total for 1904 by no less than $46,673,759, or 63.8 per cent; a gain which closely reflects the comparative conditions of the iron and steel trades.

The corporation has taken advantage of its heavy earnings for the year to make large appropriations for repairs and improvements to its existing plants; for additions to plant in the form of new mills and furnaces; and for additions to its reserves of iron ore. All these measures are wise, since they are needed to maintain its leadership and control of the trade in the future. By cutting down or omitting entirely these appropriations, it would have been possible to pay some dividend on the common stock; but the question, apparently, was not raised by the managers, and returns on the common shares seem still remote. It must be remembered, however, that the very bulk and weight of the vast property makes constant improvement an imperative policy. To stand still is the first step toward decay and future disintegration.

American Institute of Mining Engineers' London Meeting. — The following is extracted from a circular recently issued by the secretary of the American Institute of Mining Engineers:

" As already announced, the London joint meeting with the Iron and Steel Institute will begin July 23. A week will be spent in London and a week in visits to other places in Great Britain.

" For the information of the London Committee of Arrangements, it is necessary to furnish, as soon as practicable, an estimate of the probable number of attendants at the meeting.

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* " Engineering and Mining Journal."

And for the guidance of this office, in facilitating the possible formation of an excursion party, similar information is required now.

"Concerning the latter point, the following statements are presented for the information of members:

" 1. It is doubtful whether the plans of members attending the London meeting will be consistent with any arrangements for their going and returning together. Nearly all of those consulted hitherto, and expecting to attend the meeting, wish to use this opportunity for additional travel abroad. Yet there is a general desire for the social pleasure (so familiar and dear to many) of an ' Institute Excursion ' across the Atlantic.

" 2. Such an ocean-excursion could not be made in a specially chartered, ordinary steamship with the comfort now afforded by the largest modern Atlantic liners. It would be unquestionably better for the party to take passage upon one of these.

" 3. The following plan is suggested as most likely, on the whole, to accommodate those who wish to spend some additional time abroad:

" *a.* It is proposed that the party shall leave New York about the middle of July, arriving in London for the meeting which begins July 23, and (after the two weeks of that meeting and its excursions) return to New York by steamer leaving Europe the first week in September. This would allow two weeks for tours in Great Britain or elsewhere, or for the visit to Germany, mentioned below. Perhaps the allowance of an additional week would be generally desired; but, apart from this detail, the above plan is the only one which seems practicable; and, if it fails to receive sufficient support, no other will be formed. In that case, members will be left to make their own arrangements for the trip.

" *b.* For the execution of any such plan, it will be necessary to secure a reservation of the required accommodations many months in advance; and it is still more important to members individually that they should have early notice of an abandonment of an excursion plan, that they may be able to make timely arrangements for themselves.

" *c.* This office will not undertake the labor incident to the organization of such an excursion. If a sufficient number signify

a desire to take part in it, their names will be furnished to Messrs. Thomas Cook & Sons, of New York City, who will conduct further correspondence.

"*Excursion to Germany.*—A communication has been received from the Society of German Ironmasters (many members of which were guests of this Institute in 1890), cordially inviting the Institute party to visit Germany after the London meeting. The number of those who are able to accept this invitation will be reported to that society, and its arrangements for their entertainment will be subsequently announced.

"Further particulars concerning the London meeting will be given in later circulars. The foregoing comprises the points of immediate and imperative importance; and statements on other points have been postponed, in order not to weaken the force of these."

The following is extracted from a recent circular sent by the secretary of the Iron and Steel Institute:

"*Summer Meeting.* — In place of the ordinary autumn meeting, a joint meeting of the American Institute of Mining Engineers and of the Iron and Steel Institute will be held in London on July 23–29. The Lord Mayor of London has kindly consented to act as chairman of the London Reception Committee, and will give a conversazione at the Mansion House on the evening of July 24. The annual dinner will be held in the Grand Hall of the Hotel Cecil on Friday, July 27. A program of the visits and excursions to be made during the meeting will be issued when the arrangements are sufficiently matured.

"*International Congress of Applied Chemistry.*—Members are invited to take part in the Sixth International Congress of Applied Chemistry to be held in Rome from April 25 to May 3. One of the sections of the congress is devoted to metallurgy, and among the excursions will be one to the ironworks of the Island of Elba. The subscription to the congress is 16s."

REVIEW OF THE IRON AND STEEL MARKET

February has been rather a dull month in the iron trade. The late fall buying movement was so persistent that it extended through the holiday period, usually one of dullness, and the present is regarded as the postponement of the customary holiday dullness. Another heavy buying movement is expected late in the spring, probably in May. Meanwhile business consists in the filling of old contracts. Orders are being received freely against these contracts in nearly all lines. The output of the rail mills until about the middle of the last quarter has been sold; the shape mills have actual specifications booked to keep them going until some time in the third quarter; mills making other finished lines are booked until some time in the second quarter. Blast furnaces, both northern and southern, have but little unsold product for the second quarter.

On January 27, merchant steel bars for the Pacific coast were advanced $2 per ton, from 2 to 2.10 cents, delivered, and structural shapes for the coast were advanced $4 per ton, from 2.15 to 2.35 cents, delivered. On January 16 plates for the coast had been advanced from 2.15 to 2.35 cents. The freight rate from Pittsburg is 75 cents per 100 pounds, so that on shapes and merchant steel bars the Pacific coast prices are still lower than the regular Pittsburg basis which prevails for delivery to other parts of the country.

Production of pig iron and steel since January 1 has been at the greatest rate ever attained in the United States, the rate of pig-iron production having increased from a trifle under 25,000,000 tons per annum to fully 25,500,000 tons, while the pig iron is going promptly into consumption.

Pig Iron. — Steel making pig iron, which was very active in January, has been extremely quiet during February, while foundry iron has remained very quiet. Prices in all markets have become slightly weaker and in some cases are quotably lower. In no case has there been a total decline of more than 50 cents from the high point made early in the year, except

that on account of accumulation, some southern gray forge was sold at $12.25, Birmingham, or possibly $12, at a time when No. 2 was $14, Birmingham, whereas the spread should normally be $1 or $1.25. There has been plenty of spot iron in the north, where a famine was feared at this time. The good supply is due to the excellent weather which has prevailed since November, enabling furnaces to make even more than their normal outputs, when more or less interruption was expected. The weather has been cold enough to keep down the moisture in the air, while it has not interfered with the operation of furnaces, or with coke movement. Prices are now as follows: F.o.b. valley furnace: Basic, $17; Bessemer, $17.50; No. 2 foundry, $17.25; gray forge, $16.25. Delivered Pittsburg: Basic, $17.85; Bessemer, $18.35; No. 2 foundry, $18.10; gray forge, $17.10. F.o.b. Birmingham: No. 2 foundry, $14; gray forge, $12.50. Delivered Chicago: Northern No. 2 foundry, $19 to $19.25; malleable Bessemer, $19 to $19.25; Lake Superior charcoal, $20 to $20.50. Delivered Philadelphia: No. 2 X foundry, $18.50 to $18.75; standard gray forge, $16.50 to $17. Freight: Valleys to Pittsburg, 85 cents; to Chicago, $2.30. On March 1 the rates from Birmingham to interior points advance 25 cents, being then $4.60 to Pittsburg, $3 to Cincinnati and $3.90 to Chicago. To Philadelphia the rates remain at $3.50 by rail and water and $4 by all-rail.

Ferro-Manganese. — The famine in ferro-manganese is over and the market has been declining. There is scarcely any demand for spot or prompt, consumers being fairly well supplied, and some being in position to lend metal. Standard 80 per cent metal is freely offered at $85 on contracts for deliveries beginning July 1, and it is possible that about this figure could be done on deliveries beginning earlier, but consumers are disposed to await a further decline before buying. Prompt metal commands only a slight premium.

Steel. — While producers are still technically behind in deliveries of billets and sheet bars, consumers have not been suffering actual hardship. There is a limited demand for small lots for prompt shipment, on which about $27.50 could be obtained for Bessemer and $28.50 for open-hearth, but large lots could not be sold at these prices. nor is there any definite market for large lots. Wire rods are $34 to $34.50, Pittsburg.

Rails. — The heavy business in rails for the whole season has been done, and mills are sold up until some time in the fourth quarter. There is a good demand for small lots, by standard roads which have already placed contracts for their main requirements, and from trolley roads, while demand is also good for light rails. Standard rails remain at $28, f.o.b. mill, and light rails at the same price for sections 25 to 45 pounds, lighter rails being higher.

Shapes. — Business continues heavy, and mills are filled with actual specifications until the early part of the third quarter. Prices are unchanged, based on 1.70 cents for beams and channels, 15-inch and under, zees and angles, f.o.b. Pittsburg.

Plates. — Plate tonnage on old contracts has been lighter, while actual new business has also been lighter. Some of the small mills can now make prompt deliveries, while the large mills can make deliveries in about two months. Prices remain firm at 1.60 cents for tank quality.

Merchant Bars. — The iron bar market is about a dollar a ton lower all around, the regular market being 1.75 cents, delivered Chicago, 1.85 cents, Pittsburg, and $1.73\frac{1}{2}$ cents, Philadelphia. Demand is light, scrap is lower, and iron bars naturally show a tendency to decline to a reasonable parity with steel bars, which remain at 1.50 cents, Pittsburg, specifications on steel bars being good. On February 16, steel hoops were advanced $1 per ton to 1.90 cents, Pittsburg, carload and larger lots. The advance was probably made to induce specifying on old contracts.

Sheets. — Demand from store is very good, and specifications to mills on old contracts are also good, but new mill business is very light. Prices are well maintained, at 2.40 cents on black and 3.45 cents on galvanized, No. 28 gauge, Pittsburg.

Scrap. — The scrap market has become still softer, and some lots of heavy melting stock have sold as low as $15.25, delivered Pittsburg. The decline will probably outrun itself shortly, as there has been no important decline in pig iron, and the softness appears to be due simply to the fact that dealers and consumers were overloaded even for a severe winter, while there has been scarcely any winter at all. Large quantities of scrap have come into the market since last November which

ordinarily would accumulate for the spring. This scrap has been more or less digested, and the market in the spring should be correspondingly stronger. Prices delivered Pittsburg are about as follows: Heavy melting stock, $15.25 to $15.50; cast borings, $10 to $10.25; wrought turnings, $13.25 to $13.50; sheet scrap, $14 to $14.25.

Connellsville Coke. — The market for prompt coke was very weak early in February, some standard Connellsville being sold at $2.10 for furnace and $2.50 for 72-hour foundry, but the market has since become stronger, partly through fear of a coal strike, and now stands at $2.30 to $2.50 for prompt furnace and $2.85 to $3.00 for prompt foundry.

STATISTICS

Pig-Iron Production in the United States in 1905. — The following statistical figures have been published in the February 1st issue of the " Bulletin of the American Iron and Steel Association."

TOTAL PRODUCTION OF ALL KINDS OF PIG IRON.

	Gross Tons of 2,240 Lbs. (includes Spiegeleisen)
1905	22,992,380
1904	16,497,033
1903	18,009,252
1902	17,821,307

PRODUCTION OF PIG IRON ACCORDING TO FUEL USED

	Gross Tons
Bituminous coal and coke	20,964,937
Anthracite and mixed anthracite and coke	1,674,515
Charcoal	352,928
Total	22,992,380

Production of Bessemer and low phosphorus pig iron in 1905: 12,407,116 gross tons.

Production of basic pig iron, not including charcoal iron in 1905: 4,105,179 gross tons.

Production of spiegeleisen and ferro-manganese in 1905: 289,983 gross tons.

Active Furnaces.* — The whole number of furnaces in blast on December 31, 1905, was 313, against 294 on June 30, 1905, and 261 on December 31, 1904. The number of furnaces in blast at the end of 1905 was larger than at the close of any year since 1891, when exactly the same number of furnaces were active.

The number of furnaces actually in blast in the second half of 1905 was 349, as compared with 334 in the first half. In 1904 the number in blast during the last half of the year was 297, against 295 in the first half.

Building and Rebuilding Furnaces. — On December 31, 1905, there were 17 furnaces in course of erection and 3 furnaces were

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* " Bulletin, American Iron and Steel Association," February 1, 1906.

being rebuilt. Of the building furnaces 2 were located in New York, 4 were in Pennsylvania, 1 was in Tennessee, 2 were in Alabama, 3 were in Ohio, 2 were in Illinois, 1 was in Michigan, 1 was in Wisconsin and 1 was in Colorado. With the exception of the Michigan furnace all of these furnaces when completed will use coke or mixed anthracite coal and coke for fuel. The Michigan furnace will use charcoal. Of the 3 rebuilding furnaces, 1 was in Pennsylvania, 1 was in Kentucky and 1 was in Ohio. When rebuilt, all 3 furnaces will use mineral fuel.

Production of All Kinds of Rails in 1905.* — The production of all kinds of rails in the United States in 1905, as ascertained by the American Iron and Steel Association, amounted to 3,372,-257 gross tons, against 2,284,711 tons in 1904, an increase of 1,087,546 tons, or 47.6 per cent. The maximum production was reached in 1905. The year of next largest production was 1903, when 2,992,477 tons were made. The increase in 1905 over 1903 amounted to 379,780 tons, or over 12 per cent. Rails rolled from purchased blooms, crop ends, " seconds " and re-rolled or renewed rails are included. Renewed rails are rails that have been in use and after reheating are rolled down to smaller sections.

The following table gives the production of all kinds of rails in 1905 according to the weight of the rails per yard. Street rails are included.

Kinds of Rails Gross Tons	Under 45 Pounds	45 Pounds and less than 85	85 Pounds and over	Total Gross Tons
Bessemer rails	209,853	1,468,123	1,510,699	3,188,675
Open-hearth rails . .	16,409	131,501	35,354	183,264
Iron rails	318	0	0	318
Total	226,580	1,599,624	1,546,053	3,372,257

In the following table the production of all kinds of rails in 1905 is given by states.

Gross Tons	Bessemer	Open-Hearth	Iron	Total
Pennsylvania	1,095,154	18,687	. . .	1,113,841
Other states.	2,093,521	164,577	318	2,258,416
Total	3,188,675	183,264	318	3,372,257

* " Bulletin, American Iron and Steel Association," February 1, 1906.

Twenty-four plants in 12 states rolled or rerolled rails in 1905, as follows: New York, 1; Pennsylvania, 5; Maryland, 3; West Virginia, 1; Georgia, 1; Alabama, 3; Ohio, 4; Illinois, 2; Wisconsin, 1; Colorado, 1; Washington, 1; and California, 1.

The production of Bessemer steel rails in 1905 amounted to 3,188,675 gross tons, against 2,137,957 tons in 1904, an increase of 1,050,718 tons, or over 49 per cent. In the following table the production of Bessemer steel rails is given by states from 1902 to 1905.

Gross Tons	1902	1903	1904	1905
Pennsylvania	1,148,425	1,186,284	801,657	1,095,154
Other states.......	1,786,967	1,760,472	1,336,300	2,093,521
Total	2,935,392	2,946,756	2,137,957	3,188,675

In addition to Pennsylvania the states which made Bessemer rails in 1905 were New York, Maryland, West Virginia, Georgia, Ohio, Illinois, Wisconsin, Colorado and Washington.

The production of Bessemer steel rails by the makers of Bessemer steel ingots, included above, amounted to 3,135,729 tons in 1905, against 2,084,688 tons in 1904, an increase in 1905 of 1,051,041 tons, or over 50 per cent. In no preceding year had the production of Bessemer steel rails by the makers of domestic ingots exceeded 2,900,000 tons. In the following table we give the total production of all kinds of Bessemer steel rails from 1902 to 1905, the rails rolled by makers of domestic ingots being separated from those rolled by companies which did not operate Bessemer converters. During 1905 about 101,000 tons of renewed or rerolled Bessemer steel rails were produced by makers of domestic ingots. These rails are included below.

Gross Tons	1902	1903	1904	1905
By makers	2,876,293	2,873,228	2,084,688	3,135,729
By all others	59,099	73,528	53,269	52,946
Total	2,935,392	2,946,756	2,137,957	3,188,675

The total production of open-hearth steel rails in 1905 was 183,264 tons against 145,883 tons in 1904, 45,054 tons in 1903, 6,029 tons in 1902, 2,093 tons in 1901 and 1,333 tons in 1900. The maximum production of open-hearth rails was reached in 1905; the year of next highest production was 1904.

Alabama rolled almost all the open-hearth rails that were rolled in 1905 and 1904, Pennsylvania rolling the remainder in 1905 and Pennsylvania and Colorado in 1904.

The production of iron rails in 1905 was 318 tons, all rolled in Alabama, Ohio and California, and all weighing less than 45 pounds to the yard. In 1904 the production was 871 tons.

Production of Bessemer Steel Ingots and Castings in 1905. * — We present below complete statistics of the production of Bessemer steel ingots and castings in the United States in 1905 and recent years.

The total production of Bessemer steel ingots and castings in 1905 was 10,941,375 gross tons, against 7,859,140 tons in 1904, an increase of 3,082,235 tons, or over 39 per cent. The production in 1905 was much the largest in our history, greatly exceeding that of 1902, the year of next largest production, when 9,138,363 tons were made. Of the total production last year, 10,920,591 tons were made by the standard Bessemer process and 20,784 tons by the Tropenas and other modifications of the Bessemer process. Acid Bessemer steel only was produced in 1905.

The following table gives the production of Bessemer steel ingots and castings in the last four years by states. Of the production in 1905, 22,103 tons were direct castings, against a similar production of 16,051 tons in 1904.

States—Ingots and Castings	1902 Gross Tons	1903 Gross Tons	1904 Gross Tons	1905 Gross Tons
Pennsylvania	4,209,326	3,909,436	3,464,650	4,491,445
Ohio	2,528,802	2,330,134	2,050,115	3,131,149
Illinois...........	1,443,614	1,366,569	1,257,190	1,651,250
Other states.......	956,621	986,690	1,087,185	1,667,531
Total	9,138,363	8,592,829	7,859,140	10,941,375

There were no Clapp-Griffiths works in operation in 1905, and only 2 Robert-Bessemer plants were active. Twenty-five standard Bessemer plants were at work, as compared with 24 in 1904; and 13 Tropenas plants were running, against 11 in 1904. In addition, 1 plant made steel by the Bookwalter process and 4 plants made steel in special Bessemer converters. All the smaller Bessemer works make a specialty of castings, although ingots are occasionally made.

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* " Bulletin, American Iron and Steel Association," February 1, 1906.

During 1905 three Bessemer converters were abandoned and dismantled, namely, two 5-gross-ton standard Bessemer converters at Pittsburg and one 2-gross-ton Bookwalter converter at Reading, Pa.

While Pennsylvania is still far in the lead of other states as a producer of Bessemer steel it will be noticed by the table that Ohio is fast looming up as a powerful competitor. When the new standard Bessemer steel plant now being built at Youngstown is completed and put in operation, Pennsylvania's present lead will be materially reduced.

World's Pig-Iron Production in 1905, Provisional.*

	Gross Tons
United States	22,992,380
Germany	10,813,983
England	9,150,000
Belgium	1,329,109
Other countries	8,615,777
Total, 1905	52,901,249
1904	44,883,295
1903	45,696,232
1902	43,370,088
1901	40,170,583
1900	40,173,915
1890	26,980,810

Swedish Pig-Iron Production. — A provisional statement of pig-iron production in Sweden in 1905 is given at 527,300 metric tons, and this is compared with 520,300 metric tons in 1904, showing a gain of 7,000 tons. As a matter of fact, however, the official return for 1904 was 528,525 metric tons, so that really a decline of 1,225 tons is indicated. The provisional figure of 527,300 metric tons in 1905 is equal to 518,967 gross tons. The provisional figures for 1904 and 1905 in pig iron and steel are as follows, in metric tons:

	1904	1905
Pig Iron,	520,300	527,300
Blooms,	189,200	178,700
Bessemer ingots,	78,600	77,900
Open-hearth ingots,	245,500	280,200

It is stated that of this quantity, 321,200 tons were exported in 1904 and 387,600 tons in 1905.

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* " Iron and Steel Trade Review," February 8, 1906.

RECENT PUBLICATIONS

Métallurgie Générale, Procédés de Chauffage, by U. Le Verrier, chief engineer of mines, professor at the Conservatoire des Arts et Métiers.   366 6½ × 10-in. pages; illustrated; paper covers. Gauthier Villars. Paris. $3.50. — The following outlines of the contents of the chapters into which the author divides the treatment of his subject will indicate the character of this book and the field covered: Technical Study of Heat, including a description of pyrometry and of the most important pyrometers used in metallurgy; Solid Fuels: their general properties, calorific power, ignition temperature, composition, etc.; Description of Fuels, both natural and artificial, their composition, calorific power, preparation (of artificial fuels), etc.; Uses of Fuels, including a description of the various types of furnaces; Heating by Electricity; Refractory Materials, their composition, preparation, uses, etc.; Organization of a Metallurgical Plant and, as an appendix, many useful tables.   To acquire a sound knowledge of combustion and of the substances used for the production of heat should be one of the first cares of the metallurgist, and Professor Le Verrier's clear and methodical exposition can be warmly recommended to those possessing the necessary knowledge of French.

Conversations on Chemistry, Part II, by W. Ostwald, professor of chemistry in the University of Leipzig. 373 5 × 7½-in. pages; illustrated.   John Wiley & Sons. New York.   1906.   Price, $2.00. — The originality and interest of this work, to which we called attention a few months ago in reviewing the first part, is well sustained throughout the second part, which deals with the chemistry of the most important elements and compounds. While the translator of the first part was Elizabeth Catherine Ramsay, the translation of this second part is to be credited to Stuart K. Turnbull, who appears to have accomplished his work in a satisfactory manner.   While written in a familiar, conversational style, and while apparently dealing only with elementary principles, it would be a great error to infer that the

book should appeal only to beginners, for there is much in it well worth the close attention of advanced students of natural philosophy.

A Treatise on Chemistry, by Sir H. E. Roscoe, F. R. S., and C. Schorlemmer, F. R. S. Vol. I, The Non-Metallic Elements. 931 $5\frac{1}{2}$ × $8\frac{1}{2}$-in. pages; illustrated. Macmillan & Co. London. 1905. Price, $5.00. — The present edition of this important book has been completely revised by Sir H. E. Roscoe, assisted by Drs. H. G. Colman and A. Harden; it contains 217 illustrations and, as a frontispiece, a portrait of Dalton, engraved by C. H. Jeens from a daguerreotype. It is interesting to recall that the first edition of this book appeared nearly thirty years ago and to reflect upon the magnitude of the advance which has been made during that time in chemistry and the chemical arts and which are recorded in this last edition and by the same pen. This authoritative book is of great interest, not only to theoretical chemists, but also to students of applied chemistry, for much space is devoted to a careful description of manufacturing processes. The publishers present the book in a very creditable manner, the typography, illustrations, paper and binding being in every way highly satisfactory.

Les Fours Electriques et Leurs Applications Industrielles, by Jean Escard. 535 $6\frac{1}{2}$ × 10-in. pages; illustrated; paper covers. Vve. Ch. Dunod. Paris. 1905. Price, 18 francs. — The notable progress made during the last decade in the construction of electrical furnaces, and especially in their application, has resulted in a literature on those subjects which is already abundant, but in a field constantly growing the last contribution always has the advantage over its predecessors of including the very latest improvements recorded. The author of the book we have before us first describes in a general way the voltaic arc and its properties, following this by a classification of electrical furnaces. Laboratory types are described first as well as the experiments which may be conducted with their assistance, the author devoting quite a little space to the different varieties of carbon and to metallic carbides. Descriptions are given of the manufacture of calcium carbide and acetylene, of aluminum and refractory alloys and the electro-

metallurgy of iron is treated at some length. The manufacture of silicon and silicides is next treated and the concluding chapter deals with the application of the electric arc to the welding and working of metals. Henri Moissan contributes a short preface to the book.

Machine Tools and Workshop Practice, by Alfred Parr, instructor, University College, Nottingham, England. 444 $5\frac{1}{2} \times 8\frac{1}{2}$-in. pages; 510 illustrations. Longmans, Green and Co. London, New York and Bombay. 1905.— This book is written primarily for the engineering students of the University College of Nottingham, but it should prove of much interest and value to a large number of other persons interested in machine tools and their use.

American Society for Testing Materials, Vol. V. Edited by the Secretary. 565 6 × 9-in. pages; illustrated. Published by the Society. Philadelphia, Pa. 1905.— This last annual volume of the American Society for the Testing of Materials consists of the proceedings of the eighth annual meeting of the Society, held at Atlantic City, N. J., June 29, 30 and July 1, 1905. It includes the presidential address by Dr. C. B. Dudley, reports of the various committees and their discussions and a number of papers read at the meeting, among which we note: " Some Causes of Failure of Rails in Service," by Robert Job; " Rail Sections as Engineering Structures," by P. H. Dudley; " Influence of the Methods of Piling Stay-Bolt Iron on Vibratory Tests," by H. V. Wille; " A Preliminary Report on the Effect of Combined Stresses on the Elastic Properties of Steel," by E. L. Hancock; " A Comparison of Standard Methods of Testing Cast Iron," by Richard Moldenke; " The Thermit Process in American Practice," by E. Stuetz; " Pig-Iron Grading by Analysis," by Hambden Buel; " Hard Cast Iron, the Theory of One of Its Causes," by Henry Souther. This volume also includes the charter and by-laws of the society, a list of members, a description of the technical committees and their make-up and other general information.

A Manual of Assaying, by Alfred Stanley Miller, professor of mining and metallurgy, University of Idaho. Third edition;

revised and enlarged. John Wiley & Sons. New York. 1906. Price, $1.00. — In the third edition of this little book the author has attempted to give in a concise form a description of the best up-to-date methods for the fire assay of gold, silver and lead and for amalgamation and chlorination tests. The conciseness and clearness of the author's treatment are features which should appeal strongly to the student, whether or not he possesses larger books on assaying.

Eminent Engineers, by Dwight Goddard. 280 $5\frac{1}{2} \times 7\frac{1}{2}$-in. pages; illustrated. The Derry-Collard Company. New York. 1906. Price, $1.00 — In this interesting little book the author sketches in a happy vein the lives of thirty-two of the inventors and engineers " who, " to use his own words, " did most to further mechanical progress." Sixteen Americans and sixteen Europeans make up the list as follows: Benjamin Franklin, John Fitch, Nathan Read, Oliver Evans, Robert Fulton, John Stevens, Robert L. Stevens, Eli Whitney, Thomas Blanchard, Elias Howe, John Ericsson, Peter Cooper, George H. Corliss, Alexander L. Holley, William R. Jones, James B. Eads, Richard Arkwright, Thomas Newcomen, James Watt, Matthew Boulton, William Murdock, William Symington, Richard Trevithick, Henry Maudsley, George Stephenson, I. K. Brunel, James Nasmyth, Alfred Krupp, Charles Babage, Sir Joseph Whitworth, Sir Henry Bessemer and Sir William Siemens.

Portraits, for the most part well reproduced, accompany each biography. It will be noted that with only one exception, namely, Alfred Krupp (Siemens being a naturalized Englishman), the author includes Englishmen only in his list of Europeans, from which it should not be hastily inferred that England alone has produced inventors and engineers of mark. In the reading of these useful and successful lives there is much that is helpful and inspiring.

Esperanto. The Student's Complete Text-book. Compiled by J. C. O'Connor, B.A. 175 $4\frac{1}{2} \times 4$-in. pages. Fleming H. Revell Company. New York. Price, 50 cents. — The advantages which would result from an effective and universally used international language are too evident to dismiss the subject with some witty or humorous remark, and there is much in

this Esperanto to commend it to the attention of the fair-
minded and thoughtful reader. While it undoubtedly possesses
many of the essential features which should characterize an
international language, however, it is not above criticism. It
will be admitted, we think, that the fundamental principle of
such a language should be simplicity and that whenever that
simplicity is not the greatest possible, there is cause for adverse
criticism. Upon this assumption we find two or three features in
the construction of Esperanto which are disappointing. Adjec-
tives, for instance, as well as nouns have a plural form. This
is a useless complication, for it does not exist in English, where
no confusion results from it. *Forta Stalo* means strong steel,
while *Fortaj Staloj* means strong steels. *Forta Staloj* would be
simpler and for no possible reason less satisfactory. A much
more objectionable feature is to be found in the introduction of
an objective (accusative) form both for nouns and adjectives,
although there is no such form either in French or in English.
Bona fero means good iron. *Mi havas bonan feron* means, I
have some good iron. And why should this not be, *Mi havas
bona fero?* If we now combined the plural with the objective
form, I have some good irons becomes, *Mi havas bonajn ferojn* in-
stead of *Mi havas bona feroj* — surely a simpler and more pleasing
sentence. The letter *j* selected for the plural form also appears
an unfortunate choice. It does not seem as if this mechanical
language, constructed by a single man, should have been accepted
in its entirety as the international language to be adopted by
all civilized nations. A committee of properly qualified persons
should have been intrusted with its study, and, if need be,
modification. Such procedure would probably have resulted
in the elimination of these needless complications and unattrac-
tive features.

BOOKS RECEIVED

The following books have been received and will be reviewed in an
early issue of the *Iron and Steel Magazine.*

Traité de Chimie Appliquée, by C. Chabrié, in charge of the Course in
Applied Chemistry at the Faculty of Sciences of the University of Paris.
First volume. 876 6 × 9½-in. pages; 271 illustrations. Mason et Com-
pagnie. Paris. 1905. Price, 22 francs.

*The Year Book of the Scientific and Learned Societies of Great Britain
and Ireland.* Twenty-second annual issue. 309 5½ × 8½-in. pages
Charles Griffin & Co. London. 1905. Price, 7s. 6d.

Manuel d'Analyse Chimique, by Eug. Prost, D.S., University of Liège. 443 5 × 8½-in. pages; illustrated. Librarie Polytechnique, Ch. Béranger, Paris and Liège. 1903. Price, 12.50 francs.

The Journal of the Iron and Steel Institute. Volume LXVIII (No. II, 1905). Edited by Bennett H. Brough, Secretary. 879 5½ × 8½-in. pages; illustrated. E. and F. N. Spon, Limited. London. 1906. Price, 16s.

The Encyclopedia of Practical Engineering and Allied Trades, edited by Joseph G. Horner. Volumes I and II. Each volume 240 7 × 10-in. pages; profusely illustrated. Virtue & Co. London. Price, each volume, 7s. 6d.

Traité, théorique et pratique de, Métallurgie Générale, by L. Babu, chief engineer of mines, professor at the École Nationale des Mines. Volume II. 705 7 × 9½-in. pages; illustrated. Librarie Polytechnique, Ch. Béranger. Paris and Liège. 1906. Price, 25 francs.

A Technological and Scientific Dictionary. Part XII, edited by G. F. Goodchild and ·C. E. Tweney. 64 6 × 10-in. pages; illustrated. George Newnes, Ltd. London. Price, 1s. This dictionary will be completed in fifteen parts.

The Competent Life, by Thomas D. West. 268 5 × 7½-in. pages; illustrated. The Cleveland Printing and Publishing Co. Cleveland. 1905.

Doble Tangential Water Wheels. An illustrated pamphlet issued by the Abner Doble Company. San Francisco, U. S. A.
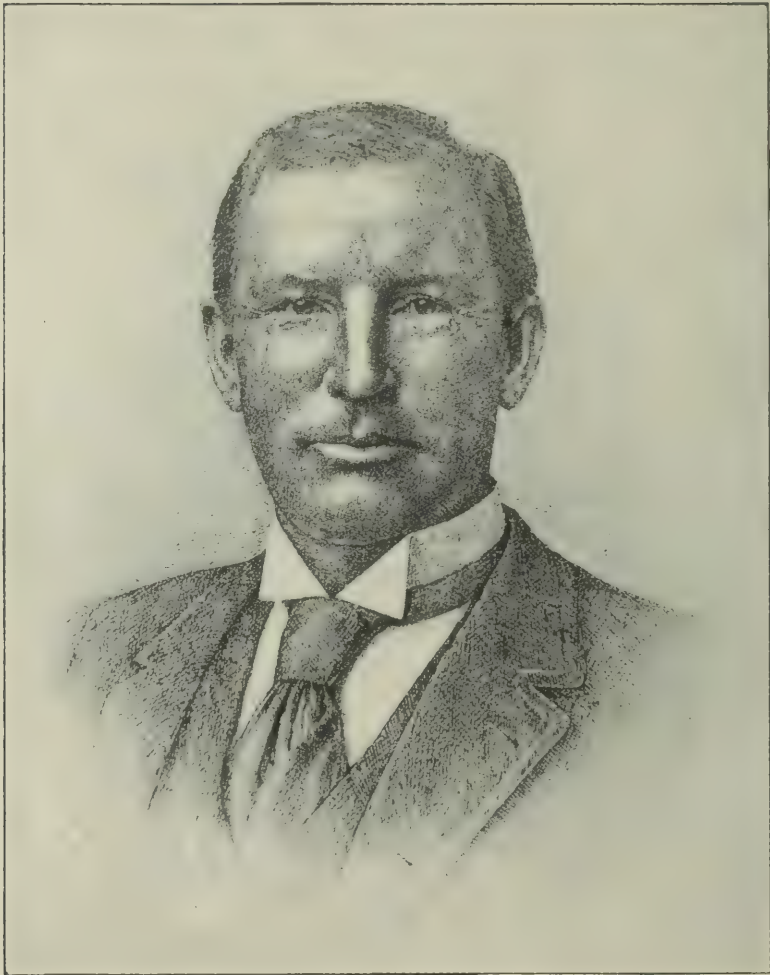
WILLIAM RICHARD JONES

SEE PAGE 334

A DEFECTIVE BAR OF TOOL STEEL *

By C. E. CORSON
Railway Steel-Spring Co., Latrobe, Pa.
Written for the Iron and Steel Magazine

THE case of the failure of a finishing tool, from a bar of steel of a well-known make, and the study of its cause by metallographic methods, may be of interest to steel users.

The tool referred to and shown in Fig 1 was put into service for finishing cuts on a boring mill and in less than two days played out, having been in use for only a very small part of this period.

The bar from which the tool was made was the regulation size, $1\frac{1}{4}$ inches by $1\frac{1}{8}$ inches in cross section, and was of crucible steel with the following composition: C 1.72, P 0.012, Mn 0.34, Si 0.17, S 0.018.

At one place in the bar, within a space of 12 inches, were found the fractures exhibited in Fig. 2. Fracture A is fine grained and silky, like a normal tool steel, while fracture B would be called "burnt" by the average blacksmith. It is coarse and brilliant except at the center.

Figs. 3 and 4 show the microstructure of the coarse-grained fracture enlarged 60 diameters. In Fig. 3 we see pearlite and cementite, the latter being in distinct needle form, while there is no network structure.

In Fig. 4, there are areas of the cementite needles and there is also a tendency to form a network, making a very heterogeneous structure.

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* Received March 12, 1906.
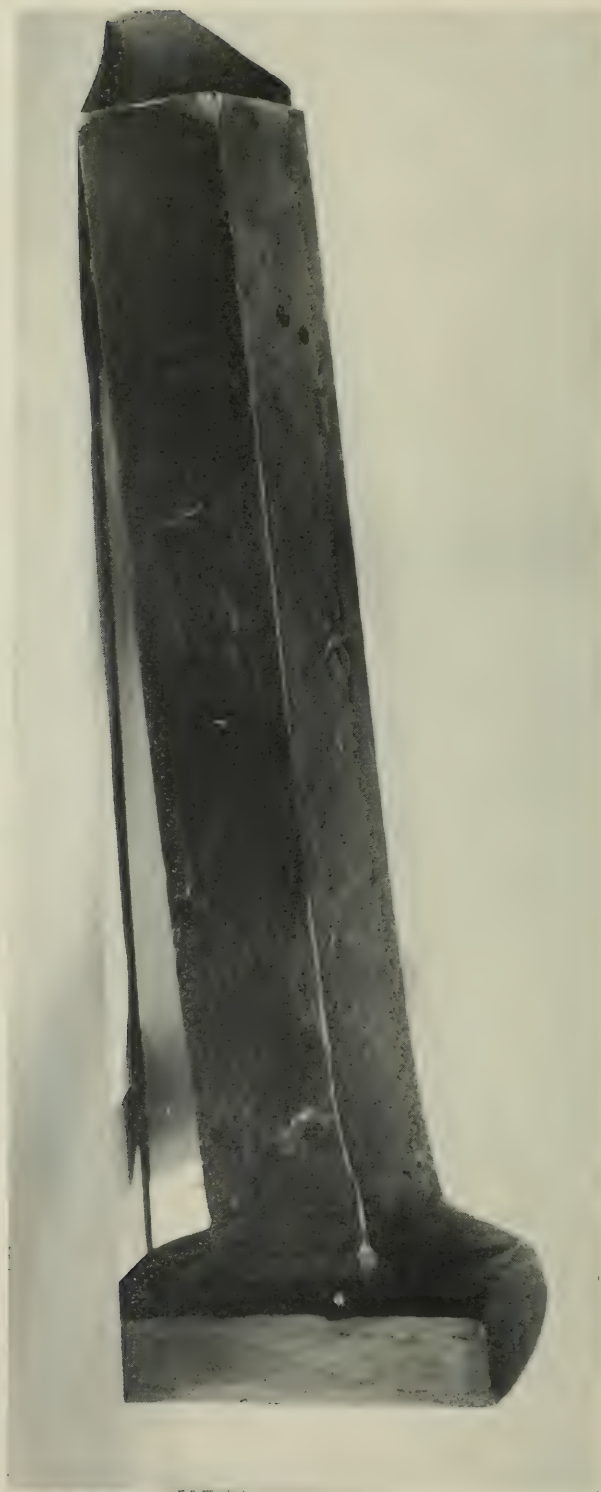
Fig. 1

Fig. 5 shows the structure (x60) of the fine-grained fracture. In this we notice a slight network.

Here, then, we find structures correspondingly as different as the two fractures. An attempt was made by treating the two pieces of steel represented in the two structures to see if they could not be duplicated.

Fig. 6 shows the structure (x60) of a piece of the fine-grained steel after being heated to 1700° F. and cooled in lime.

Fig. 7 shows the structure (x60) of the coarse grain treated exactly the same. Compare these two structures with that
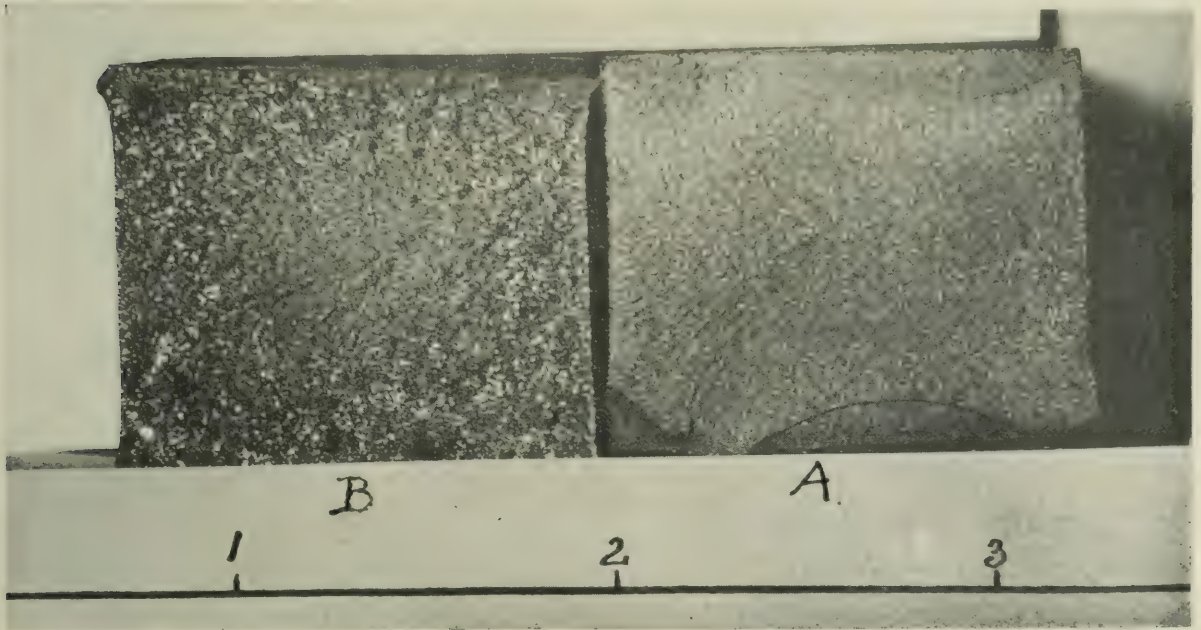
FIG. 2

shown in Fig. 3. There is more of a tendency to form a network, yet the crystallization is nearly the same.

The cementite needles are coarse and irregular. If anything, it would seem as if the original coarse grain cooled more slowly and from a higher temperature than 1700° F.

Fig. 8 shows the structure (x60) of the fine grain heated to 1700° F. and cooled in the air. Here all the cementite seems to have gone to the needle form and is so pronounced that the pearlite loses its significance.

Fig. 9 shows the structure (x60) of the coarse grain heated to 1350° F. and cooled in the air. Here we see a fine-grained structure of a properly annealed steel.
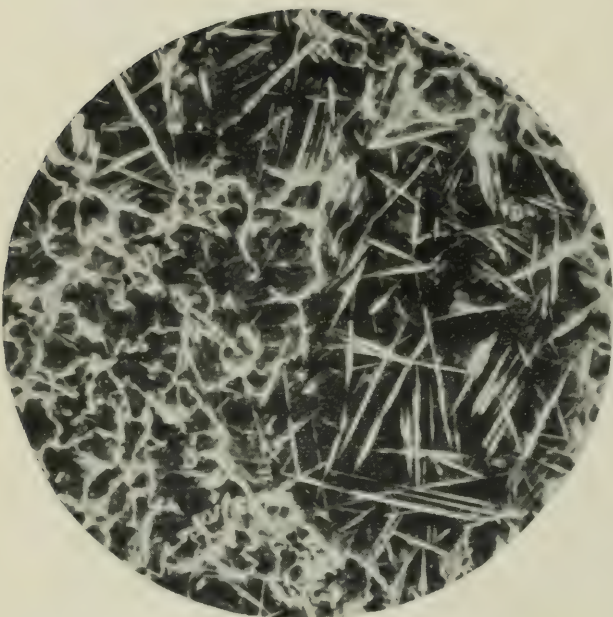
FIG. 3
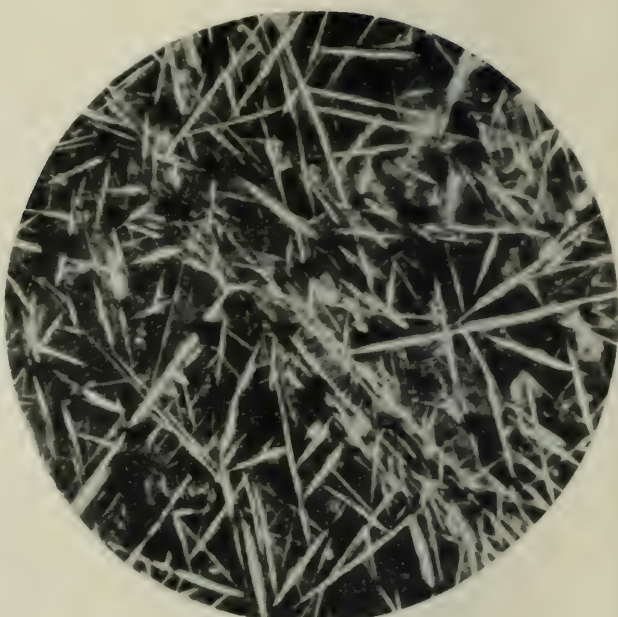
FIG. 4
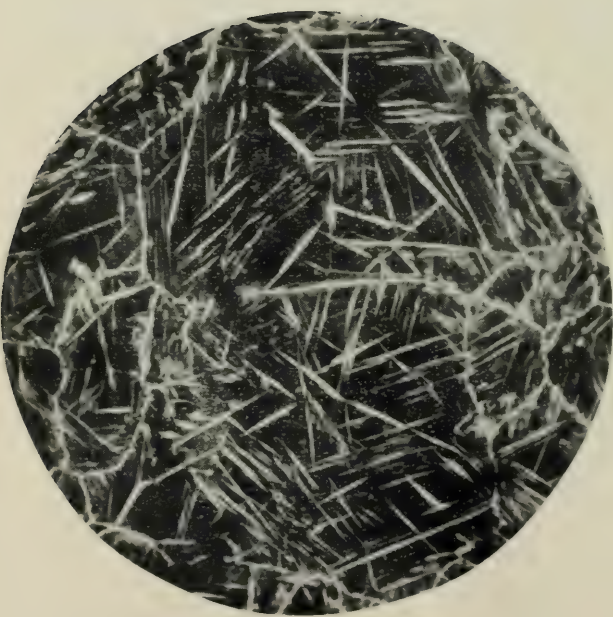
FIG 5
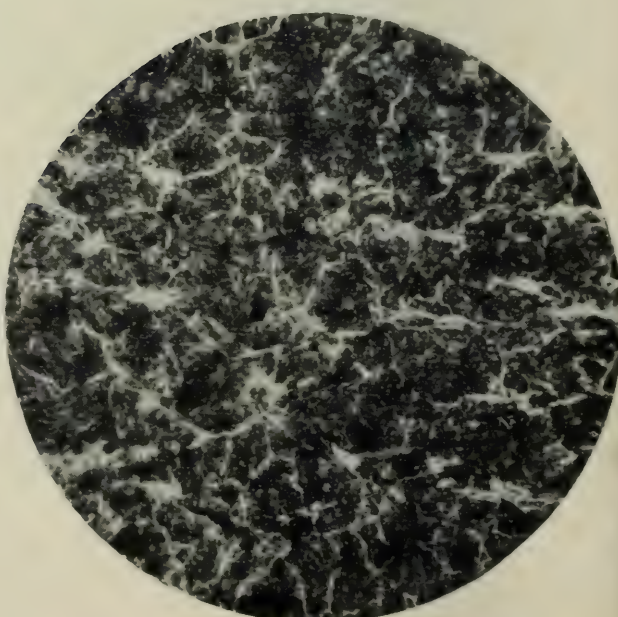
FIG. 6
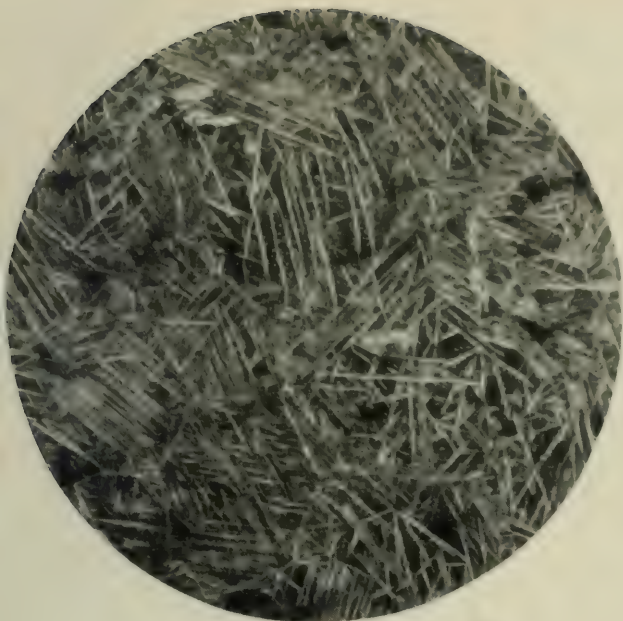
FIG. 7
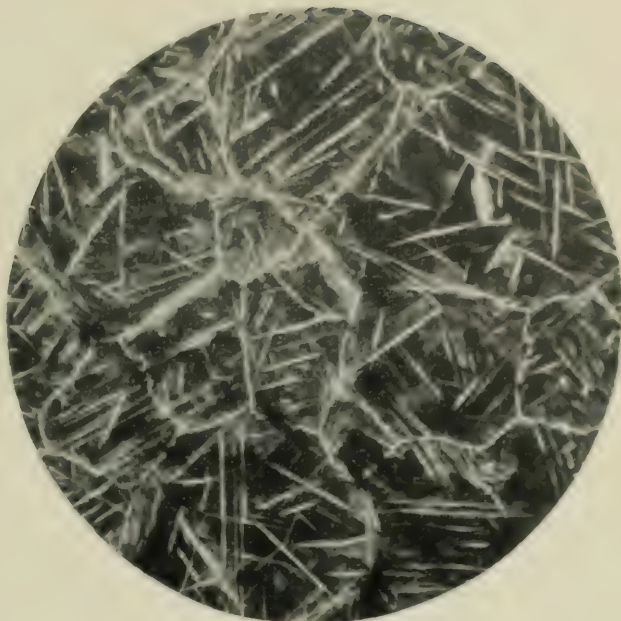
FIG. 8
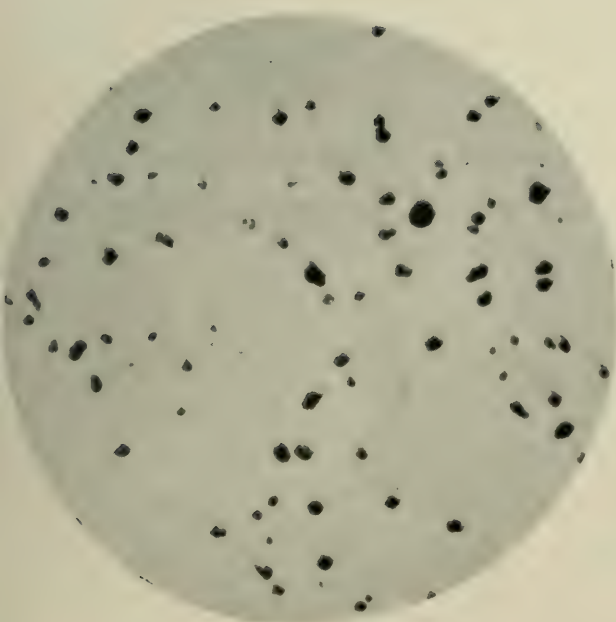
FIG. 9
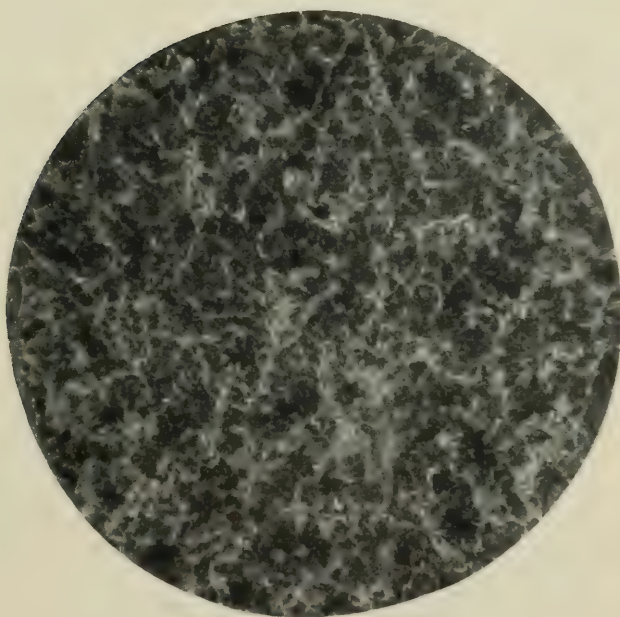
FIG. 10

From this meager data concerning the heat treatment of both kinds of the steel as represented by the two fractures it is not difficult to deduce that (1) the steel was cooled slowly in a furnace or some other slow medium, (2) that in the same bar the points from which the cooling began varied greatly.

There may be two explanations as to this condition. The bar may have been unevenly hammered, or else, after it had been partly drawn, one end may have become too cold to work and had to be reheated before finishing, producing an unequal state of crystallization.

It will be noticed that in the micrographs in Figs. 3, 4, 5 and 6 are black spots which might suggest bad places in the plate or bad work in the dark room, but it will be observed that these spots occur in Figs. 7, 8 and 9, which have received some heat treatment.

The etching from the piece of the bar from which Fig. 3 was taken was removed by repolishing it and a micrograph made (x60) of the unetched surface which is shown in Fig. 10.

These spots are undoubtedly blow holes and make the steel appear extremely porous.

Internal blow holes in an ingot are less harmful than external ones, since the former, if not too large, may be welded together by the right amount and kind of work.

Internal blow holes, moreover, in a tool steel ingot are rather to be desired since they tend to decrease the size of the pipe.

This bar gives evidence of not having received the work necessary to eliminate the blow holes.

In conclusion, it has been shown: (1) That this bar contained two very different states of crystallization as represented in the two fractures, showing that the forging of the steel has been deficient; (2) that the steel was porous by reason of containing many blow holes.

It is possible to remedy the first condition by proper heat treatment, but the second condition is almost beyond remedy, for the work necessary to make the tool is not sufficient to weld together these defects.

From these two reasons it is evident that this steel did not receive sufficient work in drawing the ingot to render the finished bar sound and capable of standing service as a tool.

DESCRIPTIVE METALLURGY OF IRON AND STEEL.* III

By SAMUEL GROVES

(Continued from Vol. X, p. 308)

ORES OF COMMERCE

AT the present time (January, 1906), five great iron ore producing centers furnish more than three fourths of the world's supply, viz., Lake Superior district, U. S. A.; Spain, of which Bilboa Province is the most important; England, chiefly in the Cleveland district of Yorkshire; Swedish Lapland and the Minette region of Germany and France, comprising Luxemburg, the adjacent portions of Lorraine and the department of Meurthe-ét-Moselle. Russia for the time being † has ceased to count. The following is a reliable ‡ estimate of the world's workable ore deposits and the present annual production, consumption and exportation:

	Workable Ore Fields Million Tons	Present Annual Output Million Tons	Present Annual Home Con- sumption Million Tons	Present Annual Export- ation Million Tons
United States........	1,100	35	35	..
Great Britain........	1,000	14	20	..
Germany............	2.200	21	24	2
Spain..............	500	8	1	7
Russia and Finland..	1,500	4	6	2
France.............	1,500	6	8	..
Sweden.............	1,000	4	1	3
Austria-Hungary....	1,200	3	4	..
Other countries.....	..	5	1	2
Totals...........	10,000	100	100	16

Having taken this generalized view, we can now descend to particulars.

Ore may be defined as a mineral or rock from which metalliferous matter of economic value can be extracted at a profit.

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* " The Canadian Engineer," March, 1906.

† Revolution.

‡ Report of Professor Törnebohm, chief of the Swedish Geographical Survey, to the Swedish government in 1905.

The compounds which constitute the chief iron ores of commerce exist in nature as oxides, that is, the iron (Fe) is chemically combined with oxygen, together with an admixture of mineral matter,— lime, alumina, magnesia, silica, carbonic acid, phosphoric acid, bisulphide of iron, manganese, etc.,—and is found in geological strata of the earth, either in rock formation, kidney-shaped lumps, soft pulverized layers, or as crystalline grains in beds of drift sand. The mineral matter associated with the oxide of iron in the ore is known as gangue; and the larger part of the metallurgical process — converting the ore from a mineral condition into a metallic state — consists in getting rid of this extraneous earthy material.

The iron ores in use commercially may be classified as follows:

Oxides	Hydrates	Carbonates
Magnetite.	˙Brown hematite.	Spathic.
		Clayband.
Red hematite.		Blackband.

Let us consider briefly the chemical constitution, physical properties, source and use of these ores in the logical order of their iron contents.

MAGNETITE

Magnetic iron ore, or magnetite (Fe_3O_4), contains in its pure state 72.41 per cent of iron and 27.59 per cent oxygen. It is the richest of all ores. In pre-scientific days this ore was popularly known as " loadstone," meaning " leading stone," from its power of acting as a magnet; hence the name " magnetite." In the lump form it is generally dense, hard and comparatively free from the ordinarily adhering metalloids, which accounts for its extensive use in the manufacture of high-class tool steel and fine cutlery; the celebrated Dannemora iron used in Sheffield was made from this ore. Magnetic iron ore is widely distributed over the globe, and is indigenous to the archaic rocks in which no organic remains are found, thus accounting for its characteristic freedom from phosphorus. It is sometimes found in the shape of dark, iron-gray, cubical or octahedral crystals, embedded in slaty rocks, but mostly in massive veins as in Sweden and India.
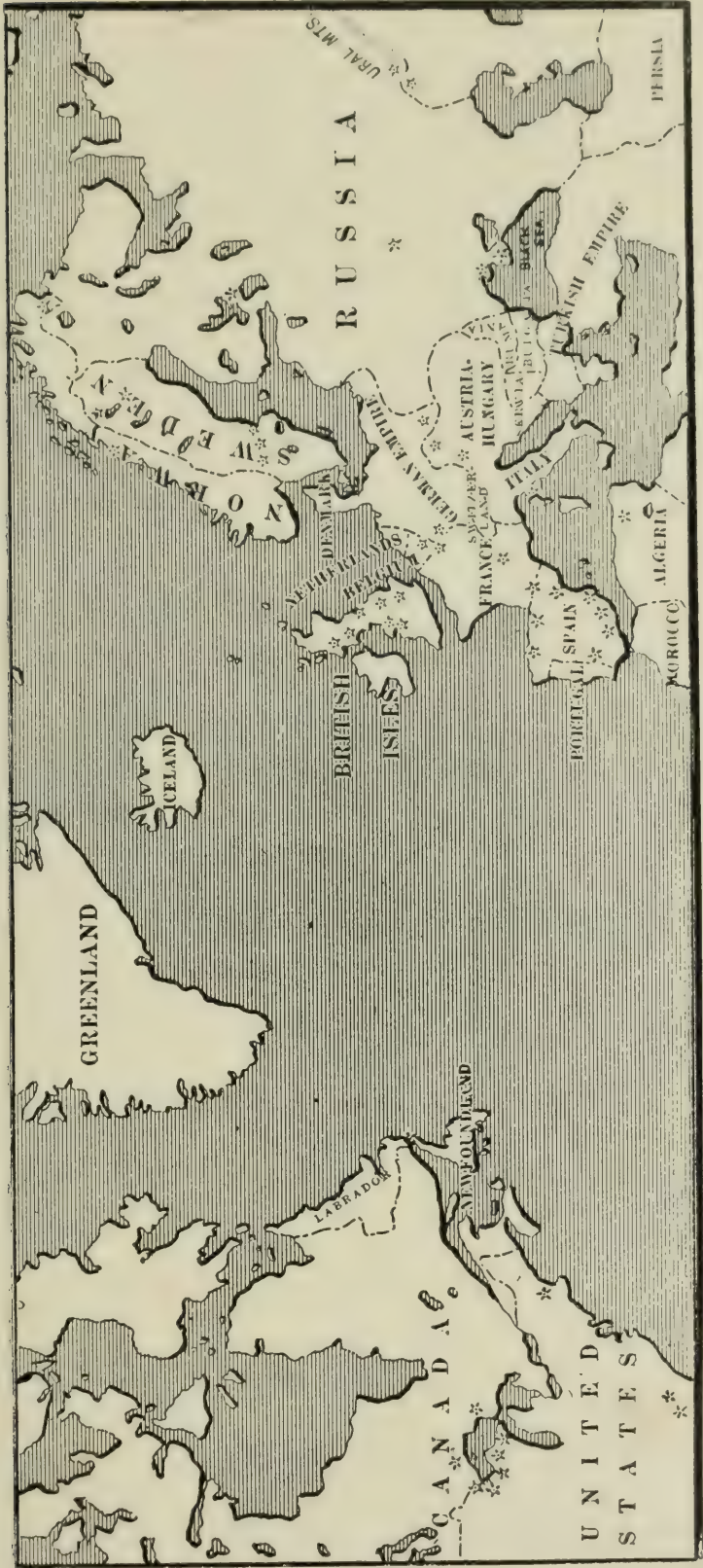
Map Showing World's Important Ore Mines. *Stars indicate locations

There was a time when " tonnage " steel-makers, especially in the United States, depreciated and almost despised magnetic iron ores, even though they may be high grade and otherwise perfect, because it had been found by experience that the hard magnetic ores would not mix satisfactorily with the soft hematite ores in the blast furnace, since they had different fusion levels, and the former needed more fuel to dissociate the gangue and reduce the iron. The United States Steel Corporation shut down all their magnetite mines simply because they could make greater profit out of the more easily reduced and less costly hematites. But recently the exigencies of competitive trade in high-grade steels has led to the sending out of search parties with dip-needle and stadia into every nook and corner of the earth. Hence, startling discoveries are constantly being announced. One day it is a solid mountain of iron in Mexico; another it is thousands of millions of tons of magnetic, crystalline grains of iron in the black sands of the Pacific coast; then a wonderful seam of rich " gray " magnetite, thirty feet thick and five miles long, on a mountain range in Talladega County, Ala. The latest evidence seems to point to Canada as possessing the richest, most extensive and easily accessible resources of magnetite suitable for high-grade steel making.

For centuries the Dannemora iron ore mines of Sweden have produced the purest magnetic iron ore known to exist, limiting the output to 50,000 tons per annum, and selling at a price almost prohibitory. This magnetite contains on the average about 50 per cent metallic iron and from 0.0025 to 0.005 phosphorus. It requires very little flux in the blast furnace, since the gangue is principally limestone, the natural flux. These mines have been worked for at least four hundred years. Recently Russia has appeared on the scene as a formidable rival, for the Ural Mountains contain immense beds of magnetic iron ore (60 to 65 per cent) and practically free from phosphorus. The political disturbances of late on the shores of the Black Sea have, however, not only hindered but practically stopped this thriving ore trade with Europe and America.

In the Lake Superior region, magnetite is comparatively scarce, the small output being practically limited to one of the Champion mines and the Michigamme Mine in the Marquette range, Michigan. In the Eastern states, however, these ores

are more plentiful but low grade and high in sulphur. In 1904 over 1,630,000 tons of low-grade magnetite was mined in the United States, chiefly in the Lake Champlain district of New York state and in New Jersey; and, as the concentrationary desulphurizing and nodule-forming process of T. C. King, operated by the National Metallurgical Company, Newark Bay, is now in successful operation, there is a likelihood of increased ore mining activity in the latter state, where large deposits of inferior magnetite exist, but which have hitherto been of little commercial value, owing to their high sulphur contents, — in the pyrites form as high as 48 per cent. In 1905, extensive beds of rich magnetic oxide (Fe_3O_4 79.06 per cent) were discovered in the black sands along the Pacific coast, south of the Columbia River, U. S. A. Experiments with a temporary electric furnace, conducted under the personal supervision of Dr. Day, of the United States Geological Survey, disclosed the fact that, out of every ton of black sand treated, 683 pounds of iron were produced. A carload of this black sand, of which there are said to be five hundred immense deposits, was found to be one third pure magnetite. "The Mining World," commenting on this important discovery, says: " It is believed that the black sands of the Pacific coast constitute the world's most valuable mineral source."

English ironmasters, face to face with the prospective exhaustion of the high-grade British ore mines, together with those of Spain, from whence of late years their most important supplies have been obtained, have secured control of immense deposits in the Dunderland district of Norway, the amount of which above the surrounding surface level alone is estimated at 80,000,000 tons, largely magnetite, containing 40 to 45 per cent of iron, and low in phosphorus. This hard ore has to be crushed, magnetically separated and briquetted. Some $10,000,000 has been spent on the enterprise already, and the whole plant is expected to be in active operation this summer (1906), mining 5,000 tons per day, — another illustration of English perpetual youth.

In the western hemisphere at the present moment the most encouraging outlook is in central Ontario, Canada. Seventy miles north of the Georgian Bay, in the Nipissing district, along the west branch of Vermilion River, and extending some thirty

or forty miles, is one of the richest magnetic iron ore deposits ever discovered. Expert evidence shows that cropping out 250 feet above the bluffs are more than 10,000,000 tons of magnetite, containing 60 per cent metallic iron, 0.05 to 0.07 per cent phosphorus, very low sulphur, and without a trace of titanium, the bane of so many Canadian ores; while below these levels are slightly inferior merchantable grades, estimated conservatively at 140,000,000 tons. Shipments of these ores by the Canadian Northern Railway down to the new piers at Georgian Bay will commence this year at freight rates which will permit delivery from the mines to pier and across the waters to Lake Erie ports at $1 per ton, which is 50 to 60 cents less than from the western end of Lake Superior. And not only has the Dominion magnetic iron ore in quantity, but in quality also. About 110 miles east of Toronto by rail and 45 miles from water navigation, at Weller's Bay, on Lake Ontario, is one of the richest deposits of magnetite in existence, estimated at the very least at 4,000,000 tons. The following analysis is taken from the official report of Prof. W. G. Miller, provincial geologist (January 6, 1906). In this report crude, sand-like ore, gathered on the surface and magnetically separated and concentrated, is said to contain:

	Per cent
Metallic iron	71.01
Sulphur	0.11
Phosphorus	0.016

" It will be seen that the metallic iron in the magnetite after concentration is only a little over one per cent below the theoretical or absolutely pure ore." The report says further: " Coarse sample of crude lump magnetite was crushed to ten-mesh by Professor Kirkpatrick (School of Mining, Kingston), and separated magnetically.

" Composition

	Per cent
Metallic iron	67.46
Sulphur	0.129
Phosphorus	0.01"

This bed of magnetite, richer in iron by 20 per cent than the famous Dannemora ores, would doubtless have been cornered long ago by eager ironmasters of the United States had it not

been for the high percentage of sulphur. But now that desul-
phurization can be achieved successfully, and at the same
time cheaply, by the King concentrationary and nodule-forming
process, it ought to be a valuable asset in the development of a
high-grade steel-making industry in Canada; and Mr. T. D.
Ledyard is to be congratulated upon his wisdom and foresight
in holding on to this valuable property until the " fullness of
time had come."

From the standpoint of the metallurgist the remarkably
high metal contents of Canadian magnetites is of great eco-
nomic importance, since " it has been found that a difference
(above 60 per cent) of five units of iron to the 100 in the burden
of ore fed to the furnace will, if properly controlled and utilized,
make a difference of about 20 per cent in the output of iron
from the furnace."* In view, therefore, of the vast iron ore
resources of Canada — raw material which has hitherto been of
little practical value, owing to the admixture of sulphur, phos-
phorus, titanium, and other excessive refractory impurities,
but which can now be removed by effective concentrationary
processes and the electric furnace, it is manifest that the
optimistic predictions of Canada's future importance as a fine
steel producing country are well founded.

(To be continued)

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* W. P. Ball, " Journal American Institute of Mining Engineers."

OPEN-HEARTH STEEL CASTINGS.* — III

By W. M. CARR

(Continued from page 231)

ACID FURNACE BRICK WORK

THE furnace body wherever subjected to uniform high temperature is lined by first-grade silica bricks. Piers and outside walls of the structure below the charging floor can be red brick; linings of flues and chambers including checkers are No. 1 firebrick. Silica brick will not answer for checking because they will crumble under the varying ranges of heat.

The hearth pan is lined with firebrick to the depth of nine inches or more, but above metal line of a fully lined hearth, the sides, walls and roof are silica. With the brick work complete the furnace is first dried moderately and carefully with a wood or soft coal fire kept going for a few days.

The gas or oil can then be turned on slightly at first and then gradually raised to nearly full working temperature. Layers of silica sand of the quality described in preceding chapters are then spread over the bottom. They are put in in succession and between each interval the flame is allowed to set or sinter the sand until hard. This operation is repeated until the hearth lining will have reached a depth of 18 to 20 inches, including the firebricks. A hearth so lined with a suitable refractory ought to last almost indefinitely under favorable conditions.

There will be occasional patching of slag line and bottom, with sand at the end of each heat, the extent of which will be controlled by the conditions and character of stock used in melting. A hearth properly lined must be set hard enough to resist attrition by the charging of melting stock. Under skillful handling an acid furnace ought to turn out normally 950 heats or more in a campaign at the rate of at least 3 heats per working day.

BASIC FURNACE BRICK WORK

The designation basic is rather a misnomer. The nature of the basic process requires a lining of such materials that will

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* "The Iron Trade Review," March 8, 1906.

resist the fluxing action of limey slags and vapors necessary to purify and refine phosphoric melting stock. Unfortunately, no materials are commercially available to completely line a furnace body, so recourse can only be had to a hearth lined with basic materials, with roof, sides and walls of furnace body above the slag line consisting of silica or acid bricks, the reasons being that bricks of basic or neutral material, such as magnesite or chrome, while being refractory, do not give as good results as silica bricks, owing to a liability to crumble if placed in the walls or roof. Therefore a basic furnace is part acid and part basic lining.

With the exception of the furnace body in regard to brick work the construction is the same as an acid furnace. The hearth pan is first lined with firebrick, followed with magnesite bricks. Usually the bottom is lined with ground magnesite. It may be mixed with about 5 per cent of anhydrous tar and rammed in to form the hearth and then slowly and carefully brought to full temperature; or the magnesite may be put in loosely in layers and gradually sintered. A small percentage of ground basic slag is sometimes mixed with it to insure a partial fusing or sinter.

A magnesite hearth, while costly, gives the best results in service and will sinter hard enough to withstand rough usage by charging of stock. Where the magnesite bricks meet the silica bricks of the walls, a parting of chrome ore is placed as a neutral separation of the two to prevent a fluxing liable to ensue between them at full working temperature.

There will always be some scorification of the hearth at the slag line and an occasional formation of holes in the bottom, due to the action of silicious matter carried in with the stock. The repairs to the hearth are made with raw dolomite on the slag line, and with ground magnesite on the bottom. Dolomite being so much cheaper it is fully as effective as magnesite at the slag line. In the raw state it is not recommended for bottom repairs, because at a high temperature it is calcined, contracting greatly in bulk, and for that reason holes in the bottom cannot be satisfactorily filled with it. Under the heat of fused stock it would loosen, float upwards and leave the condition as bad as before the patch.

Undue hearth scorification can be controlled by proper care

in the character of stock. Hence the consumption of refractories for hearth patching can be kept at the minimum figure. With proper care a basic hearth of magnesite should last indefinitely, and the life of the brick work of the roof and walls ought to yield 400 or more heats at three heats per day.

Fuel Accessories

As the choice of fuel may rest between producer gas or oil, a description of the operation of either will be briefly considered. Referring to the cut of a gas producer, a general idea will be formed of its construction. The one shown is of the simpler kind and entirely hand fed and poked. In some of the large rolling mills coal is fed in continuously by a mechanical device, and the bed of fuel is poked by a mechanical contrivance. The principle of operation is the same in either case so far as making gas goes.

For a continuous supply of gas, air and steam are forced through an incandescent bed of bituminous coal on top of which is fed at regular intervals fresh coal. Frequently the mass is poked with long bars to break up the decomposing coal and to prevent holes or passages being formed which might allow air to pass through them and dilute the gas. In the vicinity of the grate, which is water sealed, the fuel is completely burned, while that near the top gives off its volatile matter, forming copious volumes of smoke with some tarry matter. As the fuel descends towards the grate it is gradually burned to ash.

For proper working conditions the bed of coal should be kept at a constant height, and vigorous poking should be frequently and persistently followed.

The object of water-sealing the grate is to permit the amount of air necessary to gasify the coal to be under control at all times.

The use of steam lessens the temperature of combustion at the grate and so lengthens the life of the grate bars. At the same time the steam chemically combines with the fuel to form water gas, as will be shown. It also prevents the formation of clinkers, making it easier to keep the fires clean.

To make good gas the fuel must be hot, and close attention must be given to the admixture of air and steam forced into the producer. Too much steam tends to cool the fires and pass into the flues, undecomposed, causing an extravagant loss of fuel efficiency. A deep, hot bed of coal will yield the richest gas.

It will not be amiss to consider some of the chemical changes that take place in a producer. Roughly the bed of fuel in it can be divided into two zones. The lower one, nearest the grate, can be called the CO_2 zone and the upper one the CO zone. The air coming into union with the fuel near the grate forms

$$C + 2O = CO_2.$$
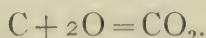
CO_2 is, of course, non-combustible, but as it passes upwards it combines with the glowing carbon of the CO zone and, absorbing some, becomes

$$CO_2 + C = 2CO,$$
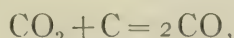
the latter constituent forming the larger volume and chief calorific agent of producer gas. By the action of steam we have

$$C + H_2O = CO + 2H \quad \text{(water gas)}.$$
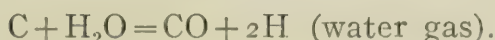
The calorific value of this last product is greater in equal volume than the CO formed in second equation but at the expense of the heat in the bed of fuel. The following is an analysis of producer gas:

	Per cent by Volume
CO	27.00
CO_2	5.00
H	10.00
$CH_4 + C_2H_4$	1.50
O + N by diff.	56.50
	100.00

The amount of oxygen in the gas will be about 1 per cent, and represents the air that passes through the producer uncombined. The index to the proper working of the producer is the amount of CO_2 present. Under the most advantageous conditions it will rarely fall below 2.5 per cent and with bad conditions it will exceed the average of 5 per cent. The causes of an excess are due to insufficient poking, a shallow fire and faulty brick work allowing air leakages to ignite the gas before it can be delivered to the furnace.

At the best, producer gas is unsatisfactory, and the steel melter is always at the mercy of the vigilance, or lack of it, of the gas man.

One ton of bituminous coal yields 160,000 to 170,000 cubic feet of gas, with a calorific value, at the producer, of about

137 B. T. U. per cubic foot. The gas in traveling to the furnace loses heat units at a variable rate. The actual amount of gas delivered to the furnace is hard to determine, owing to leakage and the consumption in drying ladles.

Liquid fuels, such as crude petroleum or residuum, possess a high calorific value, usually expressed at 14,000 to 17,000 B. T. U. per pound of oil. Because the oil being delivered directly to the furnace (see oil burning device and furnace

Detail of Washer   Special Nipple

**Oil Burner
for
Open Hearth Furnace**
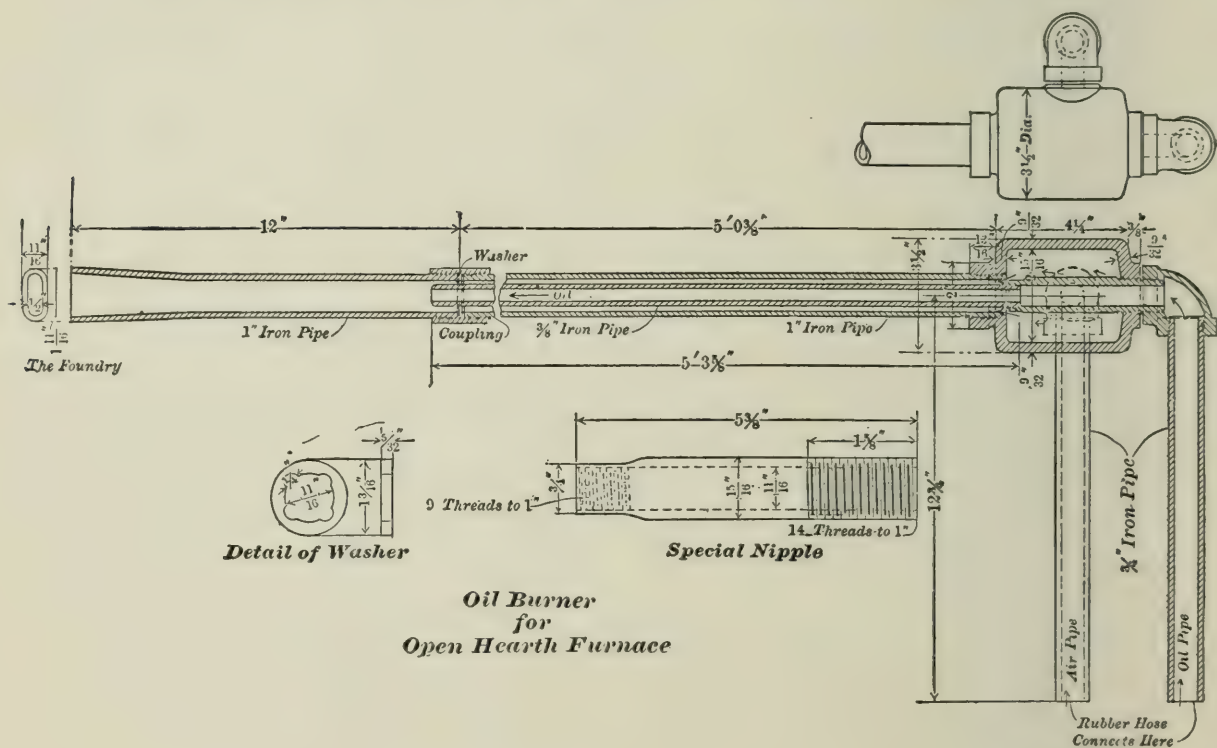
construction for same) and igniting, when atomized by steam or compressed air, yields its entire thermal efficiency to work with no intermediate losses as is the case with gas, the value of oil over the latter is marked.

It is difficult to make an actual comparison beteen oil and coal for steel melting on the basis of the cost of a ton of metal produced. The figures may be in favor of coal in certain localities, and in favor of oil in others. Yet the advantages of oil over coal in working results are so pronounced that discrepancies in cost against oil are offset by its usefulness.

Ignoring the relative costs, the principal points in favor of oil against gas will be considered:

First, the higher thermal value. A cubic foot of gas will yield 137 B. T. U. Taking 16,000 B. T. U. as an average of one pound of oil, and allowing a cubic foot of oil at 57 11-100 pounds, then 57.11 × 16,000 = 913.760 B. T. U., a substantial gain in favor of oil against an equal volume of gas.

Second, the simplicity of installation. One furnace will require a storage tank with a capacity of about 17,000 gallons;
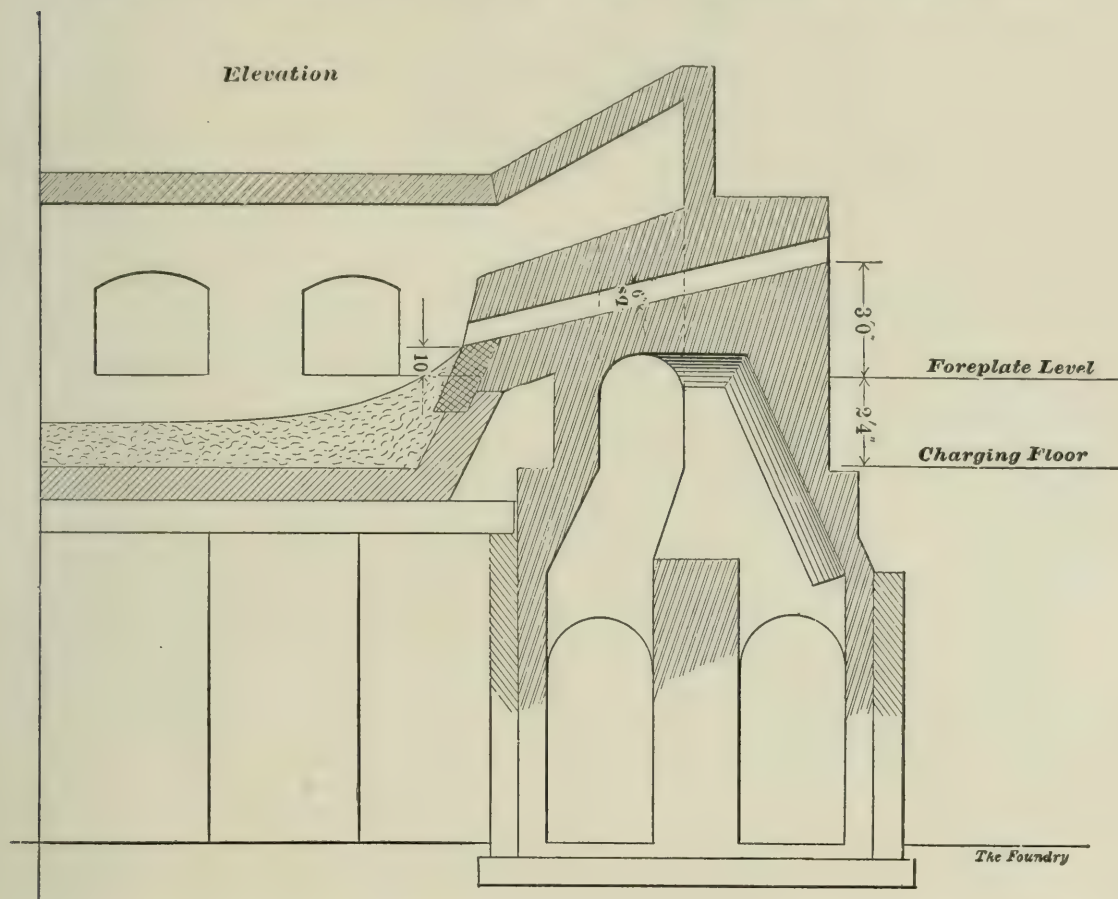
from this the oil is pumped to the burner (see cut) which essentially is the producer in the sense that the arrangement of the burner permits a necessary atomization of the oil by steam or compressed air before ignition. It is superfluous to make a further comparison on this point, in view of the crudity of the gas producer.

Third, the use of oil lessens furnace repair costs and allows longer campaigns before shutting down for general repairs. This point alone is, perhaps, the strongest one in favor of oil.

Conditions of brick work in regenerator chambers do not require the same attention with liquid fuel as they would with gas. That is to say, should there be leakages in the partition wall

Section A-B

Section C-D

Section E-F

Top View of Water Plan
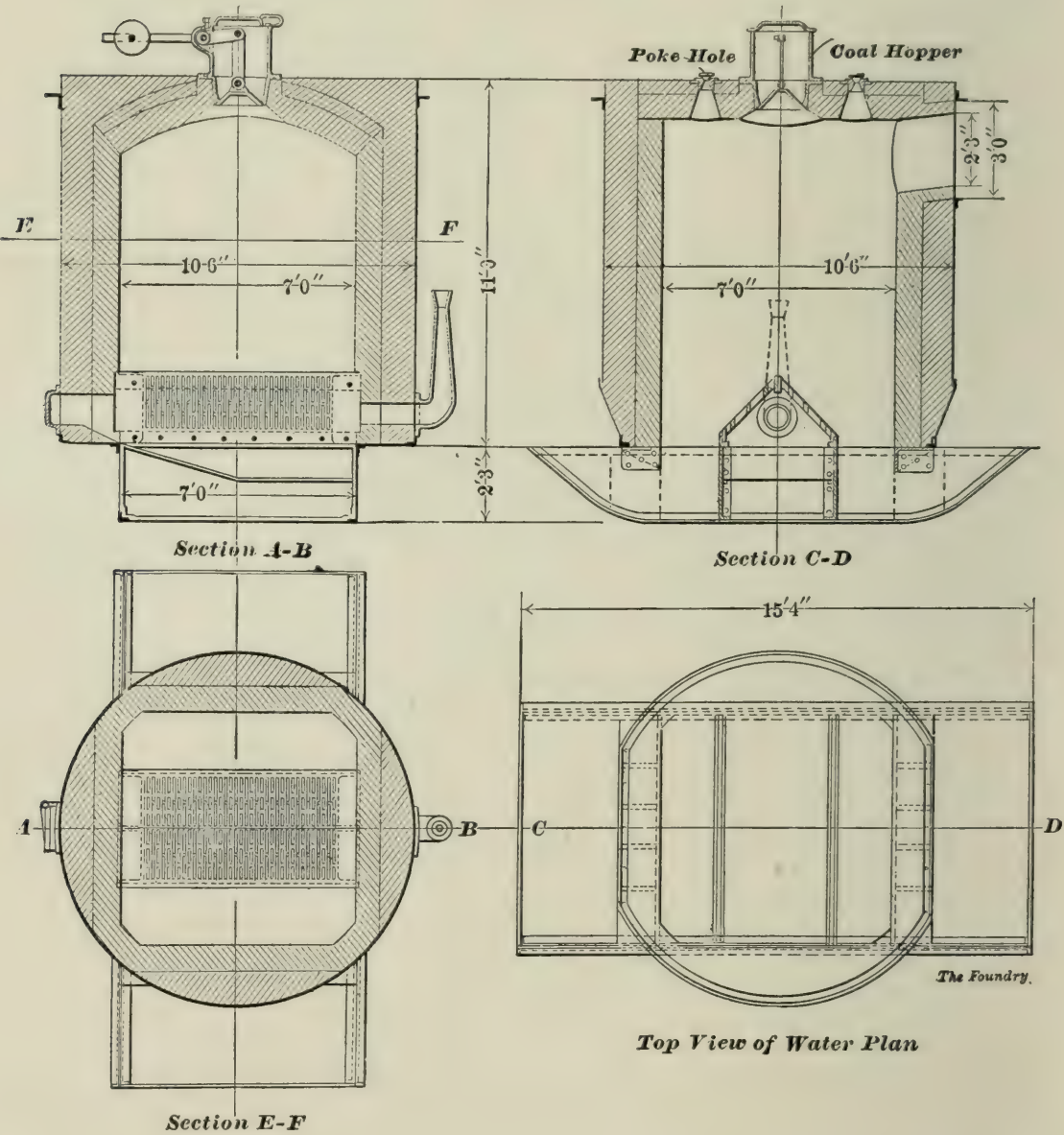
between air and gas chambers, they can be ignored, using oil; but with gas they would necessitate a shutdown of the furnace to repair them.   The same applies to ports and downtakes.

Fourth, the character of the oil not being subject to the same latitudes of irregularity as the composition of the gas, there results a decided gain in the certainty of the furnace's

work. The temperature of the bath is under control, and regularity of output can be expected — a feature not so dependable with gas.

Fifth, the labor cost is greatly lowered. One man per working day attends the pumps. In the gas house there will be a foreman and several laborers to feed and poke the fires, and to wheel away the ashes. The labor in unloading and stocking coal is also eliminated. With these features can be mentioned the removal of the attendant dirt and smoke with gas producers, the loss of time in cleaning gas mains, and other conditions that would occupy too much space to mention. Oil fuel will also be useful for drying ladles, firing annealers, core ovens, etc.

NICKEL STEEL AND ITS APPLICATION TO BOILER CONSTRUCTION *

By G. B. WATERHOUSE, New York

IT is hoped in this short article to survey rapidly the properties of nickel steels that make them specially adaptable as a material for boiler construction. It is impossible in such brief space to do more than mention the very peculiar properties possessed by some of the nickel and iron alloys, such as the loss of magnetism, although both the component metals are magnetic, and the almost complete loss of expansion with increasing temperatures. The subject will be considered under the following heads:

> Definition of Nickel Steel.
> Boiler Plate.
> Flange Steel.
> Tubes.
> Rivet Steel.
> Welding Properties.
> Gain in Strength or Saving in Weight.
> Noncorrosion.
> Finally, a brief Conclusion and Bibliography.

DEFINITION OF NICKEL STEEL

Nickel steel may be defined as ordinary steel with its properties modified by the presence of nickel. The proportion of

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* " The Iron Age," February 8, 1906.

the added element, nickel, is usually from 3 to 3.5 per cent, but in special steels it may rise to as high as 30 per cent.   These last mentioned cases are really alloys of iron and nickel, not proper steels, because the carbon is usually very low.

BOILER PLATE

Steels for this use are most conveniently produced in the open-hearth furnace, the process allowing both care in pro-duction and the manufacture of the large quantities so often needed.   As a consequence the composition is similar to that of usual open-hearth material, or possibly a little better, because greater care is used with the addition of the nickel.   The special high percentage alloys are often made by the crucible process. The properties of ordinary boiler plate are well known, and as nickel steel has been used in this way for some time it is possible to draw a comparison between them.   An average of the tests of very many steels of closely related composition and treatment gives the following figures:

ANALYSIS

	Carbon	Silicon	Man-ganese	Sulphur	Phos-phorus	Nickel
Per cent..	0.25	0.02	0.58	0.02	0.03	..
Per cent..	0.24	0.023	0.66	0.021	0.02	3.43

MECHANICAL TESTS

Elastic Limit Pounds	Ultimate Stress Pounds	Elongation in 8 Inches Per cent	Reduction of Area Per cent
36,064	64,260	26.6	58.2
57,344	87,561	23.2	54.4

From these it may be seen how greatly the tenacity of the steels is raised by the addition of the nickel, while the ductility, as shown by the elongation and reduction of area, is not greatly lowered.   An eminent Scotch steel maker, William Beardmore, said in 1896, when speaking before the Institute of Engineers and Shipbuilders of Scotland: " In nickel steel of 0.26 per cent carbon, we have a metal whose elastic limit is equal to the ulti-mate strength of ordinary carbon steel.   It has all the properties of high carbon steel without the dangerous brittleness of the latter."

It is significant to notice the increased ratio of elastic limit to ultimate strength possessed by the nickel steel, which allows a much safer working margin. This is particularly important in consideration of the fact that is being emphasized more and more by the foremost experimental workers in iron and steel, namely, that a steel may be apparently all right, but under rapidly alternating stresses, such as a boiler plate is subjected to, may completely fail. At first, considerable difficulty was experienced in rolling plates of nickel steel, due to the formation of a tenacious black scale, especially on the under surface, that got worked into the plates, producing ridges. This objectionable feature was only incidental to the introduction of the new material, and with care it was soon found out how to roll the plates properly.

The loss of strength due to the effect of punching is less with nickel steel plates than ordinary ones. After careful investigation Mr. Beardmore says that ordinary mild steel loses 33 per cent of the original strength, but that the loss in the case of nickel steel varies from only 15.5 to 20 per cent. This is rather a high figure for carbon steels, a good average being 25 per cent, but still nickel brings about a great advantage. It is also said that punching leaves a clean hole, with no slivers or wire edges, and, according to Commander J. G. Eaton, nickel steel plates shear more neatly than those of carbon steel.

Flange Steel

Many tests have been made with flange steel in a similar way to those with boiler plate. An average of the results obtained at the Cleveland rolling mill on specimens cut from plates gave the following figures:

Analysis

	Carbon	Manganese	Sulphur	Phosphorus	Nickel
Per cent..	0.10	0.27	0.04	0.048	..
Per cent..	0.18	0.36	0.04	0.045	2.7

Mechanical Tests

Elastic Limit Pounds	Ultimate Stress Pounds	Elongation in 8 Inches Per cent	Reduction of Area Per cent
35,240	54,450	27.4	54.0
47,080	65,760	24.7	52.0

The addition of the 2.7 per cent of nickel to this grade of steel has increased the ultimate strength 20 per cent, while the ductility is only slightly lowered. Here again it should be noticed that the ratio of the elastic limit to the ultimate strength has been raised by the addition of nickel. Experiments have been made in flanging nickel steel plates of every thickness suitable for boilers that prove it to be worked without difficulty. It can be readily forged and pressed into dies without cracking, and the large elongation enables it to be worked with great advantage.

TUBES

The tubes are the part of the boiler that give the most trouble. Lieutenant Parks of the United States Navy said, in the discussion on a recent paper, that they had tried everything in the navy — charcoal iron, hot drawn steel tubes, cold drawn steel tubes, Bessemer steel tubes and open-hearth steel tubes — without finding a material that was satisfactory. The use of an iron-nickel alloy with 30 per cent nickel provides a material that gives great satisfaction. The French, who have been pioneers in the nickel-steel industry, first made high-percentage nickel tubes in 1898. They have been adopted in the French navy, although the complete tests are not given.

Tubes containing about 25 per cent nickel have been thoroughly tested by Mr. Yarrow, the well-known English ship builder and boiler maker, and his conclusion is that " a boiler would require to be retubed two and one-third times as often with mild steel tubes as it would with nickel-steel tubes." He subjected the tubes in his tests to the action of acids, of fire and of superheated steam. The English navy has treated similar tubes under boiler conditions, and the results are said to be in support of Mr. Yarrow's conclusion.

In 1903 the Shelby Tube Company exhibited samples of these tubes at the Saratoga railroad convention. They were made from 30 per cent nickel steel manufactured by the Bethlehem Steel Company, and the difficulties had been so far overcome that they were made in nearly the same number of operations as the ordinary seamless tubing. They fulfill the specifications of the Bureau of Steam Engineering of the Navy Department for carbon-steel, seamless, cold drawn, marine boiler tubes.

The special features of these tubes are their noncorrosiveness, their increased tensile strength and their greater life compared with ordinary steels.

Rivet Steel

Nickel steel would seem to have a good opening as material for rivets. Some very interesting and important experiments have been made by Maunsel White, whose name is so intimately connected with the introduction of high-speed tool steels. The results showed that nickel-steel rivets could be safely worked within perfectly reasonable limits, and with the exercise of only ordinary care. Tests were made with the rivets in comparison with ordinary rivets in both single and double shear, and the heats used were purposely varied from a bright red to almost white.

Mr. White says that it may be safely deduced from the results that a three-quarter inch nickel-steel rivet would replace a 1 1-16 inch or possibly a 1⅛-inch common steel rivet, thus effecting a considerable saving of plate section and giving increased strength. Other experiments have shown that nickel steel is much superior in shearing strength to ordinary steel, which lends support to Mr. White's conclusions.

Welding Properties

The welding properties of nickel steel have been extensively studied. One series of tests was made with a steel containing 3.40 per cent nickel and 0.31 per cent carbon, which is higher carbon than boiler material would be. This steel hammered like a hard steel but welded perfectly; and when bent, either hot or cold, twice at right angles at the weld, showed no crack, nor could the weld be seen.

Even with the 30 per cent nickel tubes welding is possible, and this is evidenced by the fact that many short pieces of this alloy have been welded to ordinary steel tubes, to act as " safe ends " and pass through the flue sheets. Here their elastic limit, which is greater than that of ordinary steels, enables them to stand much better against the expansion of the flue sheets.

It may, however, be taken as a rule that nickel makes the steel harder to weld, the cause being a thin film of oxide that clings to it, of the same nature as the tenacious scale found when rolling the first plates.

GAIN IN STRENGTH OR SAVING IN WEIGHT

The facts given in the previous sections show that if the nickel steel is taken of the same thickness as ordinary steel, and used for plates, flanges, rivets, or other purposes, the result would be a great increase in strength. The ductility is only lowered a little, the ultimate strength is raised and the elastic limit is also raised, more in proportion than the ultimate strength, thus giving the boiler a higher safe working limit.

If it should be desired to keep the materials of the same strength as carbon steel there comes at once, and without risk, a great saving in weight. In a very interesting paper by A. L. Colby on " Noncorrosive Boiler Tubes," careful calculations with regard to this saving in weight are given. In the case of the torpedo boat destroyer *Hopkins* there would be a saving of 29 per cent if its carbon-steel tubes were replaced by 30 per cent nickel steel; and the battle ships *Rhode Island* and *New Jersey* would lose 26 per cent of their total weight of tubes.

The lighter gauge of tubes and thinner plates would also bring about further economy because of the increased steam raising capacity the fuel would have.

NONCORROSION

The resistance of nickel steel to corrosion has been a very vexed question, some experimenters being sure that it is not much superior to ordinary steel, while others are equally emphatic that it is greatly superior. A great deal was said in the early days of nickel steel about its absolute resistance to corrosion. R. A. Hadfield, the well-known metallurgist and discoverer of manganese steel, says in regard to this: " It seemed to be forgotten that the basis of nickel steel was iron and that in the nature of things, unless an extraordinary transformation in molecular structure was obtained, of which there was no proof, the behavior of the basis, iron, while modified in the higher nickel percentages, would much resemble that of mild steel."

Experiments to determine the resistance to corrosion have been carried on in many ways, such as immersing the steel for various periods in fresh water, both cold and boiling, in solutions of different salts, in acids, and by putting plates in sea or river water for long periods of time. Mr. Yarrow's experiments on the boiler tubes of European make, containing about 25 per cent

of nickel, showed that the average loss in weight of plain carbon steels, when immersed in hydrochloric acid, was $16\frac{1}{2}$ times that of the nickel steel. The oxidizing effect with heat caused a loss in weight of the carbon steel tubes of about 77 per cent, but only about 26 per cent with the nickel steel.

When the tubes were subjected to the action of superheated steam internally, and to that of an oxidizing flame externally, the carbon steel lost 13 per cent in weight and became unfit for use, while the nickel steel lost 2 per cent and was in good condition.

On the whole, the results show that the steels with from 3 to 3.5 per cent nickel are not greatly better than ordinary steels, but that the higher percentage steels are very decidedly superior.

Conclusion

From the different sections into which this article has been divided, it is hoped that the eminent suitability of nickel steel and high-percentage nickel alloys for boiler construction has been made clear. The price of the material is rather a serious matter, because to the cost of ordinary carbon steel is to be added that of the nickel. As has been pointed out, however, less nickel steel may be used to obtain the same strength, and its longer life and superior qualities also atone for its higher price. Again, when the steel, after wear, is only fit for scrap, it may be sold to manufacturers of nickel steel for prices proportional to the nickel it contains.

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PIPING IN STEEL INGOTS *

By N. LILIENBERG

DURING the past few years the requirements for steel have
been raised so high that soundness is more important than
ever before.   The old practice was to make steel ingots of suffi-
ciently large sections to permit a considerable reduction of area
in rolling and hammering to a given size, relying on the fact that
by such rolling and hammering all cavities will be squeezed
together and practically eliminated.   The finished sizes, if found
by inspection of the surface to be faultless, were therefore pro-
nounced to be sound.   But, when such steel is worked up, the
manufacturer is surprised and disappointed to find that it splits,
or that streaks and seams make the product unmarketable.

Large sections, such as rails, beams or heavy forgings, may,
within certain limits, be sufficiently strong, even if the sides of
the cavities are only squeezed and not welded together.   But
it is well known that in the interior of heavy articles, under cer-
tain conditions, forging may develop small streaks into large
cavities.   Small sections, steel for ordnance and tubes and
numberless articles in the tool trade, always show up the defects.
It may be doubted whether cavities in steel ingots can ever be
completely welded.   The old theory is that the silver-clear blow
holes, without the blue oxide, can be welded by sufficient work-
ing.   They are, however, not empty, but are filled with carbonic
oxide.   It is admitted that the blue cavities, resulting from air
mechanically drawn down into the mold during the casting, can
never be welded, because the oxide does not melt and there
would be no escape for it if it did.   The only way in which steel
can be made satisfactory for the above-named particular pur-
poses is by having it dead molten.   But then the trouble of
piping is encountered.

As is well known, a pipe is the result of the contraction of
the liquid interior after the surface of the ingot has become solid
by contact with the mold.   When this contraction is partly
taken up by blow holes there is, of course, less sinking of the
metal at the top.   The soundest steel, therefore, has the worst

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* Read at the Bethlehem meeting of the American Institute of
Mining Engineers, February, 1906.

pipe. Some manufacturers, having found that, for certain pur-
poses, piping is a worse evil than blow holes, are therefore
purposely casting honey-combed ingots. Several manufacturers
rely on casting steel at such a temperature that the blow holes
arrange themselves in a zone midway between the center and
the surface, thus making the defects visible after rolling or
hammering. But, aside from the impossibility of always arrang-
ing the gas bubbles in this way, the defects will afterwards appear
in working, as above mentioned. The pipe is always coated with
blue oxide from contact with the air. This oxide is formed
instantaneously; and, therefore, the common practice of filling
up the pipe with liquid steel during casting and solidification only
forms a stopper which is not welded to the ingot.

A great many processes have been invented to obviate
piping. Those of importance may be arranged in two classes:
keeping the steel liquid and compression of the steel.

I. Keeping the Steel Liquid as far out toward the Mold
    as Possible, in Order to get an Even Sinking of the
    Top Surface.

All methods working on this principle suffer from the evil
that, the period for solidification being prolonged, the separa-
tion of the impurer, and therefore lighter, steel has more time
to take place, and the segregation will be more pronounced.
Under this heading the following methods may be mentioned:

1. *Addition of Aluminum*, either in the ladle or in the molds.
The aluminum increases the heat by combining with part of the
dissolved oxygen, and, at the same time, lowers the melting
point of the steel (which, of course, works in the same direction).
It is well known, however, to-day that aluminum does not realize
the expectations formerly entertained concerning its use. It
makes somewhat sounder steel, but it does not prevent piping;
and it has been found in many instances to have the tendency
to throw a bridge of solid, sound steel over the top of the ingot,
thus hiding a large, unseen cavity in the interior.

2. *Addition of Thermite.* — This mixture of aluminum and
iron oxide gives a greater heat than aluminum alone, on account
of the extra supply of oxygen present; and its use makes the
steel in the mold fairly sound. But, inasmuch as the higher
temperature cannot prevent the steel from solidifying first in

the outer layers, a pipe will nevertheless form, although it will be somewhat smaller.

3. *Use of Clay-Lined Funnels.* — These, placed on the top of the molds, shorten the pipe because the steel does not chill so rapidly against the less conductive clay as against the bare mold.
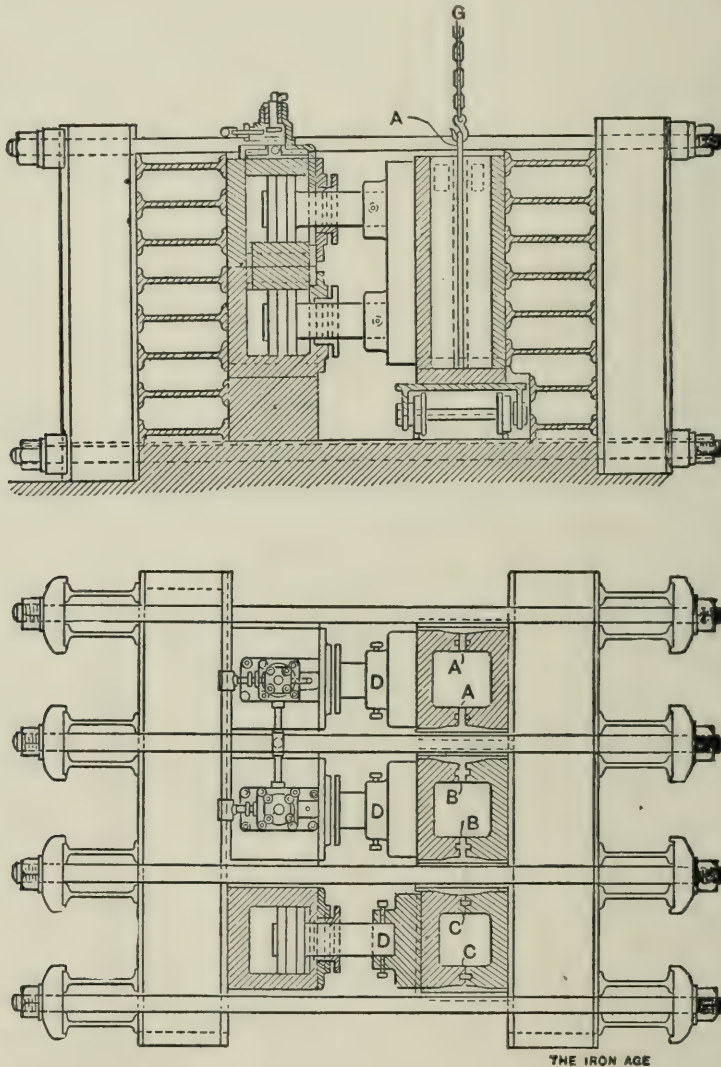
FIG. I. Longitudinal Section and Plan of the Illingworth Casting Machine for Large Ingots in Molds and Wheels

The upper part has then to be carefully cut away so far down as to leave no part of the pipe. The exact distance from the top at which the ingot should be cut is somewhat difficult to determine, both in this case as well as in the common practice of cutting off the upper part of the ingot and leaving only the lower

part for use. In both cases the production is burdened by the considerable cost of fuel, labor and waste involved in remelting the upper or piped portions of the ingots, or of selling these portions at the scrap price, which is below cost.

4. *Casting by Overflow from One Mold to Another.* — In this method the molds are arranged in a row close to one another; and while tolerably sound ingots are obtained, there is the disadvantage that much scrap is formed by the steel running through the conduits. It is also obvious that the steel coming to the last mold is much cooler than that in the first.

5. *Use of Electricity.* — In order to heat the upper part of the mold, this method has sometimes been used to prevent the chilling of the steel in contact with the sides before the center gets solid. It is obvious, however, that in order to be effective the heat would have to be so great that the mold would be destroyed by the steel which would readily attack the walls. Moreover, the method is considerably more costly than that of cutting off the piped part.

II. Compression of the Steel in the Molds

Much has been said and written about liquid compressed steel, and the general opinion seems to be that, aside from the obliteration of the pipe, little or nothing is gained by compressing liquid steel, which is absolutely sound and dead molten. Since liquids in general are inelastic, and therefore incompressible, the possible degree of compression for liquid steel depends on the included gases. If the press is arranged so that these gases, which are elastic, have no avenue of escape, the effect of the compression will only be to leave cavities of smaller size. I need hardly say that the compression of liquid steel in the mold has quite a different effect from that of forging the ingot afterward. In the latter case, the object is to change the structure of the steel at the same time with its shape. Among the numerous devices for compressing steel in molds the following three methods may be mentioned:

1. *Pressing from the Top.* — While there is no difficulty in this method, if the whole charge goes into one mold, the machinery will be considerably complicated if several ingots of smaller sizes have to be cast. These ingots will have to stand on trucks and move in procession under the press; or several presses will

have to be arranged with additional complications.   It is almost impossible to time the casting and the pressing in harmony.   If the latter is done too early the cavities will continue to form in the interior of the steel.   If too late, the pipe is already formed and oxidized, and, therefore, will only be squeezed together, but not eliminated.   Any compression from the end of an ingot is attended with the danger of tearing the interior loose from the
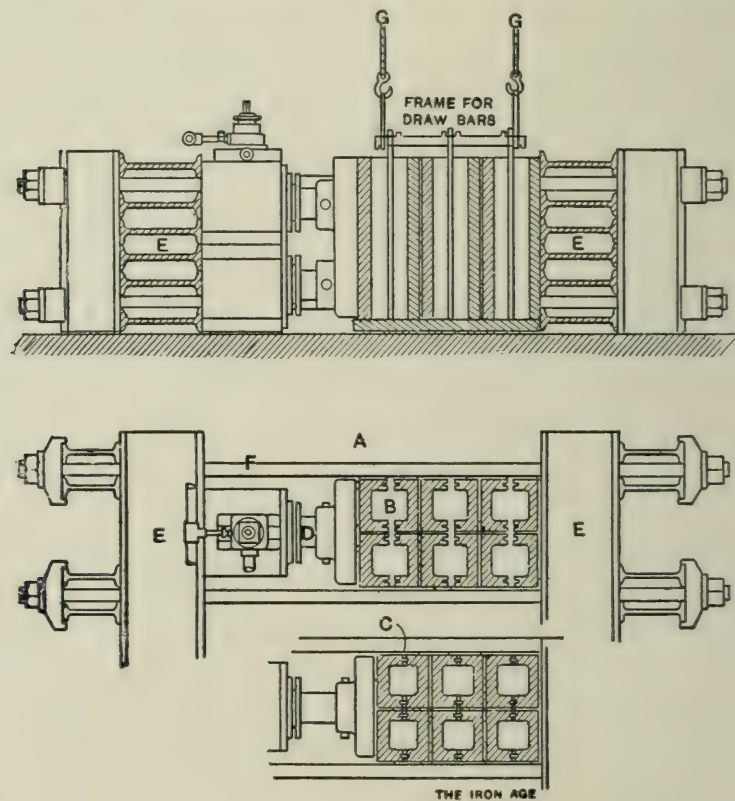
FIG. 2.   Longitudinal Section and Plan of the Illingworth Casting Machine for Small Ingots in Groups

surface.   This process is in use in some places in England and Germany.

2. *Compression from the Bottom.* — This idea originated in practice at St. Etienne, France; and the process is in use at several French works.   It naturally suffers from all the disadvantages of the top compression, and, in addition, the hydraulic machinery is contained in a deep pit, which makes it difficult to be cared for and also exposes it to slag, dirt and accidental spirts or leaks of liquid steel.   In both cases the molds have to be made sufficiently strong and correspondingly heavier and

more expensive. It is, of course, a special and simpler case where the whole charge is poured into one mold, as, for instance, in making a gun of large size.

3. *Compression from the Sides.* — In this method the top is left open, permitting the gases to escape, and the pressure is applied directly in proportion to the formation of the pipe, so as to keep the ingot always full to the top. It is obvious that the pressure can be better timed in this way than in the preceding cases.

Some years ago an apparatus of this kind was built in Pittsburgh, having four slowly moving rollers in the same plane. The ingot, with liquid interior, was taken from the mold and placed between the rollers; and as it slowly moved downward the compression kept the liquid steel toward the top and prevented the formation of pipe. This is undoubtedly the right principle; but it encounters the insurmountable practical difficulty of transferring the semi-liquid ingots from the mold to the rollers, where they are also liable to be warped and twisted. Moreover, if liquid steel be shaken, it is liable to become honey-combed by the escape of part of the gases dissolved in it.

Side compression in a stationary mold, having none of the objections above mentioned, is now successfully carried out, even with the largest sized ingots. This has been mainly accomplished by John Illingworth, who, for a long period, has devoted his large experience to the practical solution of the problem and has obtained many patents in this field.

Mr. Illingworth began by casting a continuous ingot through a prolonged vertical mold, the lower half of which was cooled by circulating water. The ingot dropped down through the bottomless mold and was broken off by a hydraulic clutch while still red hot. This method, which worked very well for small ingots, presents difficulties for the larger sizes. The second group of Mr. Illingworth's inventions comprises casting machines, built on the principle of hydraulic rams, which squeeze the two halves of the mold slowly together after they have been sufficiently opened to enter a plate between the ingot and the mold. This plate, having the section of a segment of a circle, displaces a corresponding volume of the semi-liquid interior. The two halves of the mold are drawn apart as soon as a thin skin is formed, holding the liquid steel during compression. The

movement of the molds, which are placed close together, is made by drawbars connected with the head of the hydraulic rams. This apparatus has given very satisfactory results for small ingots cast from crucibles, but it is not well adapted for casting from a bottom-tapped ladle into large molds. A special apparatus on the same principle was built for this purpose, but the experiments were not continued sufficiently long to secure successful results.
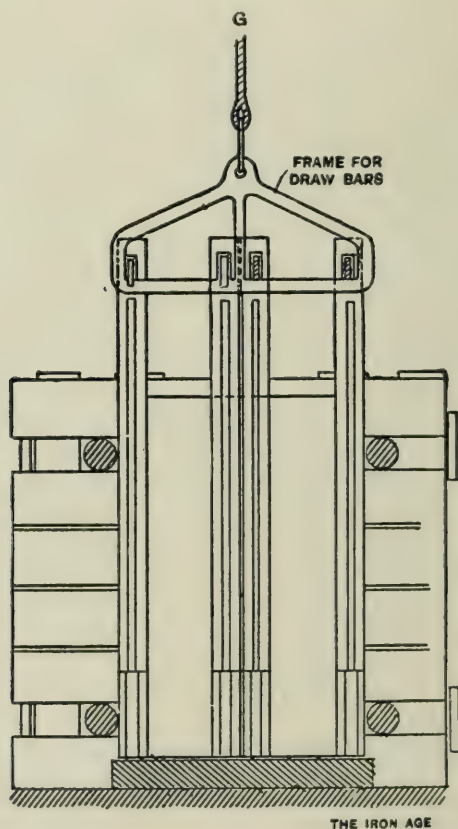
Fig. 3. Transverse Section of the Illingworth Casting Machine for Small Ingots in Groups

The problem of compressing large-sized ingots, cast from a ladle, is, however, now completely solved. Mr. Illingworth, together with S. Robinson, has built such casting machines at the steel works of Jessop & Sons, Sheffield, England, which uniformly turn out ingots of the largest size, absolutely solid from top to bottom.

There are two kinds of casting machines, one for large and the other for small ingots. Figs. 1, 2 and 3 illustrate the construction and working of these machines. The principle is to

cast the steel in molds divided in halves and held together during the casting by hydraulic pressure. In the planed side edges of the molds are grooves which admit bars of a cross section shown at A, Figs. 1, 2 and 3. After the metal has been poured into the mold sufficient time is allowed for a crust to form while the interior is still liquid. The bars are then withdrawn by chains, G, suspended from an overhead hoist, which leaves an empty space between the two halves of the mold, as shown at B. Hydraulic pressure is then applied from the ram D, and the outer half of the mold is moved forward slowly, so that the liquid interior is always kept full to the top until the mold is closed, as shown at C. The volume of the bars corresponds as near as possible to the volume of the cavities which would otherwise be formed.

The large machine, shown in Fig. 1, is for large ingots cast on trucks, which are transported out of the foundry immediately after casting, each ingot to be compressed separately. This action can be so modified that three 2-ton molds can be compressed at one time.

The small machine, Figs. 2 and 3, is designed to compress ingots of smaller sizes that are cast in groups on the ground, as shown at H. In this case the casting must be made simultaneously in all the molds in order to have the same initial temperature. This effect can be done by bottom casting or by pouring the steel from the ladle through an under hanging trough provided with a hole for each mold. With bottom-cast ingots the gates break off during the movement of compression. These illustrations have been prepared more for demonstration than for working drawings. For clearness, several details of construction have been omitted. These details have to be modified to suit each particular case.

The hydraulic cylinders on the one side of the press and the back of the molds on the other are supported by six I-beams (EE, in Fig. 2) laid horizontally on pieces formed to fit them, and held together by vertical beams and screw bolts.

In regard to the details of working the Illingworth press, three or four men can cast and compress six ingots, 13 inches square and 40 inches long, in an hour's time. The edges of the molds have to be planed, but a mold can be used for about 125 beats before this repair is needed.

It is impossible to give general statements of the cost of operating this press, since the economy would have to be calculated for each particular case.

By careful investigation it has been shown that:

1. During compression the surface of the ingot is neither crushed nor folded, but is merged in the mass, the same as in the roughing mill, although the circumstances attending compression are not so favorable as those of rolling.

2. No groove is formed between the joints of the mold. If, for special steels, there should be some tendency to this it is easy to make the edges of the bars slightly convex, thus leaving concave grooves in the ingots, which by compression straighten out to a plane.

THE TALBOT CONTINUOUS STEEL PROCESS AND ITS BENEFITS IN STEEL MAKING *

By G. A. WILSON

IN resigning my post as steel superintendent at Britannia Works, I took up a similar position with the Cargo Fleet Iron Company, Limited, of Middlesbrough, who were then on the eve of starting the first of their 175-ton tilting furnaces, as designed for the carrying out of the Talbot continuous process, and in this position I have been enabled to gain considerable experience in the working of this process.

The steel plant at Cargo Fleet Works at present consists of three large tilting furnaces, which have a nominal capacity of 175 tons each, but which will in reality at a pinch carry 200 tons of steel.

The dimensions of the bath of these furnaces are as follows:

Length between blocks, 37 feet 6 inches; width between linings, 14 feet 6 inches; depth of bath, 3 feet 10 inches to foreplate level.

The furnaces are of the Wellman type, and are provided with three rockers and supports, upon which the furnace rolls forward. Despite their large size, they are provided with only three ports — that is, one central gas port and two air ports. The ports are egg-shaped in section; and this form I find to stand remarkably well. Each port is about 2 feet 3 inches

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* Paper read before the West of Scotland Iron and Steel Institute.

across by some 3 feet 3 inches high. The air chambers are
10 feet wide by 22 feet long by 17 feet 6 inches to crown of roof.
The gas chambers are 8 feet wide by 22 feet long by 17 feet 6
inches to crown of roof. The air valve is 4 feet 3 inches square;
gas-reversing valve, 3 feet 6 inches diameter; gas-supply valve,
4 feet 6 inches diameter.

The furnace is capable of tilting both ways, and is manipu-
lated by two hydraulic cylinders in the ordinary way. The tap-
ping platform is attached to the framework of the furnace, and
consequently moves with it — a very convenient arrangement.

On the charging side the three furnaces are served by two
40-ton overhead electric traveling cranes, which are provided
with 20-ton auxiliary lifts. On the tapping side the furnaces
are served by two 75-ton overhead electric traveling cranes,
which are also supplied with 20-ton auxiliary lifts.

The lime and oxide additions are charged in by means of a
Wellman charger, which runs the whole length of the staging,
and picks up the necessary boxes from the cars on a track
running in front of the furnaces.

The molten iron is run direct from the blast furnaces to a
mixer of about 180 tons capacity. The mixer is of the ordinary
Bessemer type, and is kept sufficiently hot by means of four
blowpipe nozzles, in which coke-oven gas and air are consumed.

This arrangement is both cheap and effective, and is prac-
tically doing the work which is done at some other works in large
primary furnaces supplied with regenerators, valves, stacks, etc.

From the mixer the partly desiliconized and desulphurized
pig iron is poured into a ladle holding some 25 tons, and lifted
up and carried along by means of the overhead traveling crane
to the front of the furnace on the charging side. It is then
tilted, and the metal allowed to run slowly into the Talbot
furnace, through a short runner fixed on to the foreplate of one
of the doors.

The metal is tapped into a 50-ton steel ladle in the ordinary
way by opening the tap-hole and tilting the furnace as far as
may be desired. It is, of course, easy to regulate the exact
quantity that should be cast at one time; and when sufficient
steel has been run into the ladle, all that is necessary is to tilt
the furnace back again into its original position.

Arrangements are made for tapping off the slag whenever

desired; and this forms an essential point in a well-designed Talbot plant, as one has not only to deal with large quantities of steel, but also large quantities of slag, and the days in which we could allow this to run into the pit have long passed.

At Cargo Fleet, slag can be cast simultaneously from doors Nos. 2 and 4 on the charging side of the furnace. The slag runs into two slag ladles, which carry about 10 tons each, and which run on rails between the center stands of the furnace. The slag bogies can be run out to the casting side of the furnace to a point at which the 75-ton crane can pick them up and deal with them.

The furnaces are provided with Talbot movable port ends, which are certainly very convenient. These consist of two movable cages, one at each end of the furnace, which carry the flues or uptakes connecting the chambers with the movable section of the furnaces.

They are actuated by means of hydraulic cylinders, and have both horizontal and vertical motions. The vertical motion is very slight, being about 3-inch rise, just to prevent friction horizontally when the furnace is tilting; but when repairs have to be made to the blocks or to the uptakes from the chambers, they can be drawn back to a distance of several feet from the furnace, so as to allow the bricklayers to work either at the blocks or uptakes.

The whole furnace is water-cooled, there being separate vertical chills for the gas and air, both on the tilting section and on the movable port ends. When the furnace is working, these chills are close together.

The gas-producer plant, which has been erected at Cargo Fleet for supplying gas to the three large tilting furnaces, consists of a plant of ten Talbot mechanical gas producers. These are automatically fed, the coal being supplied from an overhead bin.

As is fairly well known, these producers, which are some 10 feet in diameter, are supplied with a central shaft, provided with an arm which works in the fire. The central shaft has both a vertical and horizontal motion; the horizontal motion being a slow continuous one, whilst the vertical motion is only used intermittently — say, once every half hour, or thereabouts. By these two motions the fire is kept in good condition, and a very good gas produced. Each producer is capable of gasifying about one ton of fuel per hour.

Casting is carried out at Cargo Fleet on the car system, there being no pit in front of the furnaces. The ladle, with from 50 to 60 tons of steel, is lifted by means of the overhead crane to the requisite position over the track upon which the cars carrying the ingot molds run. The cars are pushed forward by means of hydraulic racks; the teemer stands on a platform at about the level of the top of the ingot mold. It is rarely necessary to box down any ingots.

Having now briefly discussed the plant in which the process is carried out, let us turn for a few moments to the process itself.

I assume that you are all acquainted with the general outlines of the process, and that you have probably read Mr. Talbot's papers given before the Iron and Steel Institute in 1901 and 1903, in which are to be found full details of the process and its advantages.

Briefly, we are bringing the iron from the mixer in lots of some 20 to 25 tons each, converting this into steel, and casting about 50 tons of steel ingots every six hours. To bring this about, the great secret is the proper management of the slag, and a sufficiently decarbonized bath, when the molten pig iron is run in.

Our great aim is always to get a good reaction when the molten metal enters the bath; and if we fail to get this, we know that the charge will be a slow one, requiring to be worked down much as an ordinary heat in the ordinary fixed furnace practice.

On the other hand, when a good reaction is obtained (and this, with a little experience, the first hand can almost always bring about), the carbon is very rapidly and energetically boiled out of the metal, and when the reaction has calmed down the bath will be found to contain not more than about 3 per cent of carbon.

Some care is required to keep the reaction under control, as, if too large a quantity of molten iron is added at a time, it is apt to become too violent, when a good deal of slag which would be valuable in the furnace is thrown out on to the staging. With a high silicon iron or with a very gray iron the tendency is to get violent reactions; whereas with a good white basic iron there is very little to be feared on this score.

Immediately after tapping, as soon as the tap hole has been closed, the requisite amount of iron oxides and lime are

added to the furnace by means of the Wellman charger. Whilst these additions are getting molten, the necessary repairs to the slag line are made by the furnace hands. I may say here that we find the repairs to be considerably less on these large tilting furnaces than in the ordinary fixed basic furnaces.

As soon as the oxide and lime additions are fairly incorporated in the slag, the first ladle of molten iron is brought up from the mixer and cautiously added as described. When this has worked down somewhat, more lime and oxides are charged in, and the second ladle of metal introduced. There is always far less danger of a violent reaction with the second ladle than with the first. It is usual to run off a fair portion of the slag after the second ladle has worked down somewhat, otherwise an unduly thick slag will accumulate on the surface of the bath; and this tends to keep the heat off the metal for finishing purposes.

When the bath seems about ready, tests are taken and analytically examined for carbon, phosphorus and sulphur; and when these are found correct, the furnace is tapped.

No manganese is added in the furnace, but is all thrown into the ladle in the usual way. It is interesting to note, as showing the unoxidized state of the Talbot bath at tapping, that 25 per cent less ferro is needed than would be required to give an equal manganese in steel from a fixed furnace working the usual way.

The first charge was made at Cargo Fleet on September 4, last; and for the first twelve weeks there were produced 11,574 tons of ingots, or practically 1,000 tons per week, with a yield of 105.7 per cent of steel calculated on the metals charged, and with a speed of conversion of 8.4 minutes per ton converted.

The fuel consumption has not been quite accurately obtained, owing to gas being used for other purposes; but a near approximation brings it out at 5 cwts. per ton of steel. The tonnage rate for labor has not yet been fixed, so that I do not propose to deal with this point, but it is obvious that as the same number of men are employed as on an ordinary 50-ton basic furnace, which would make, say, 450 tons per week, labor must work out considerably less per ton.

As showing the quality of the steel produced, I give the analytical details of the first fifty casts. The steel is of excellent

quality, and has been accepted by Lloyds and other surveyors for shipbuilding.

ANALYSES OF STEEL

Cast No.			Carbon	Sulphur	Phosphorus	Manganese
1			.25	.034	.032	.420
2			.23	.032	.025	.530
3			.18	.024	.064	.610
4			.23	.041	.030	.570
5			.22	.021	.050	.610
6			.19	.050	.055	.600
7			.19	.046	.058	.610
8			.15	.049	.062	.570
9			.18	.024	.049	.480
10			.22	.044	.037	.478
11	Average analysis of metal		.18	.037	.034	.570
12	direct from blast furnaces		.22	.032	.040	.500
13	for first 26 casts		.16	.041	.025	.500
14	Phos. 1.50		.15	.039	.020	.520
15	Sil. 1.25		.15	.039	.049	.540
16	Sul. .10 to .15		.15	.035	.037	.520
17			.20	.044	.013	.450
18			.16	.037	.058	.610
19			.19	.052	.040	.570
20			.31	.055	.055	.490
21			.20	.044	.054	.490
22			.16	.058	.021	.500
23			.135	.053	.034	.490
24			.190	.058	.035	.590
25			.240	.032	.052	.480
26	The mixer was put into oper-		.140	.050	.039	.570
27	ation from cast 26		.150	.050	.039	.570
28	1.00 Sil.	.046 Sul.	.120	.050	.020	.438
29	.89	.062	.135	.050	.016	.410
30	1.12	.046	.240	.036	.017	.480
31	.93	.047	.160	.032	.021	.500
32	.745	.044	.160	.046	.040	.520
33	1.07	.086	.180	.061	.053	.490
34	1.30	.062	.170	.057	.060	.490
35	1.12	.052	.170	.053	.054	.480
36	.896	.090	.150	.040	.048	.470
37	1.06	.086	.180	.060	.038	.440
38			.155	.032	.047	.460
39	1.19	.042	.160	.040	.040	.430
40	.934	.070	.190	.025	.027	.410
41	.88	.084	.170	.058	.021	.410
42	1.17	.083	.155	.159	.032	.470
43	1.02	.084	.135	.054	.016	.450
44	.630	.064	.135	.053	.016	.450
45	1.00	.059	.135	.040	.038	.470
46	.965	.046	.150	.047	.023	.450
47	.78	.067	.170	.058	.024	.480
48	1.23	.082	.150	.055	.030	.553
49	1.17	.096	.220	.049	.050	.500
50	1.09	.063	.220	.050	.039	.480

As a rule the carbon in the steel is required fairly low, from about .15 to .20, but both higher and lower carbons can readily be obtained, more especially with very soft steel.

Hitherto we have not paid very much attention to obtaining a marketable slag, having directed our attention to making a good steel.

The pig iron used is Cleveland forge, and at times the sulphur in this is higher than could be wished. Passing such iron through the mixer, however, eliminates some 30 to 50 per cent of the sulphur and the remainder is easily dealt with in the steel furnace.

There is no doubt a mixer is a great help as an auxiliary to the steel furnace, and our experience at Cargo Fleet shows that the mixer need not be of the expensive description that has recently been adopted by several firms.

As regards the future, we hope to have our third Talbot furnace working in a few weeks. A cupola plant will have to be erected to supply part of the metal, and with this our output should be over 3,000 tons per week.

In my paper to-night I have shown you that from one large tilting furnace, without expensive scrap, and from common molten iron, we are making by the continuous process and with the help of the ordinary staff of furnacemen only, from 1,000 to 1,200 tons of steel per week, with a yield of steel up to 108 per cent on the metals charged into the furnace and with a fuel consumption of not more than 5 to 6 cwts. per ton of ingots, and I would ask those of you who have charge of open-hearth, steel furnaces to compare this with your own practice.

REFRACTORY USES OF BAUXITE *

By A. J. AUBREY

BAUXITE is a hydrated oxide of aluminum corresponding to the chemical formula $Al_2O_3 . 2H_2O$, although the proportion of water varies greatly and the aluminum is sometimes replaced by iron. Silica and titanium oxide occur as impurities. The silica varies widely in different deposits. Other oxides of aluminum containing water are diaspore ($Al_2O_3 . H_2O$), and gibbsite ($Al_2O_3 . 3H_2O$). These are found in small quantities, however. The oxide of aluminum, known as corundum (Al_2O_3), is found in still smaller quantities than the above, so that bauxite is the only oxide of aluminum found in considerable quantities. There are three localities in the United States where bauxite has been found in commercial deposits, viz.: in Arkansas, New Mexico and the Georgia-Alabama district. The last-named district has probably been worked out by this time, and at present the chief sources of the ore are the Arkansas deposits.

The crude bauxite is washed at the mines to remove some of the free silica. It is next calcined at a temperature of 2500° F., approximately Seger cone 12, and during this process it gives off its chemical water, amounting to about 30 per cent of the raw ore, and also undergoes great shrinkage. It has been observed that the bauxite shrinks very little until after Seger cone 9, approximately 2390° F., is reached, and from Seger cones 9 and 12 the greatest amount of the shrinkage takes place. Accordingly, the lowest temperature limit at which bauxite should be calcined is 2500° F.

An analysis of washed calcined bauxite from Arkansas made by the writer is as follows:

	Per cent
Mechanical water	0.88
Silica	6.40
Fe_2O_3	1.43
Alumina	87.30
TiO_2	3.99

The calcined material can be bonded with fireclay, sodium silicate or lime, and made into brick and tile. As little as 4 per cent plastic fireclay can be used for a bond for hand-made brick. When bonded with lime the brick becomes quite hard a few hours after making, so hard that they will not take the impression of the finger nail. This setting or hardening is probably due to the formation of a calcium silicate between the lime and the free silica analogous to the setting of silica brick when bonded with lime. After a careful drying treatment the brick are burned in down-draft kilns at a high temperature, and when burned they are hard and tough and can be thrown to the pavement or batted vigorously against one another without breaking. A brick 9 inches by $2\frac{1}{2}$ inches by $4\frac{1}{2}$ inches weighs 7.5 pounds, and stands a crushing test of 10,000 pounds per square inch.

The problem of calcining the washed granular bauxite presents itself. It cannot be successfully calcined in a vertical shaft kiln, because it will pack and clog on account of its fineness, and so obstruct the passage of the kiln gases. On the other hand, it is not feasible to calcine it in the ordinary down-draft kiln on account of the perforated floor. The writer believes that to calcine it on a commercial scale would require a rotary kiln using oil, gas or powdered coal for fuel, preferably the former. Provided the cost of fuel is low at the mines these kilns should be installed there in order to save the cost of transportation, which is now paid on the 30 per cent of water that the crude bauxite contains.

Steel Furnaces

For basic open-hearth steel furnaces a brick high in alumina and low in silica is required. A brick of this character is obtained in the following way: A pure white variety of the pisolitic bauxite, which has already been washed at the mines and a portion of its free silica removed, is selected and sieved. All the fine material passing through the sieve is rejected, as it contains the greater part of the silica. The pisolites, or pebbles about the size of peas, are retained, as they are higher in alumina and freer from silica than any other part of the bauxite. Now, by using lime selected for its freedom from silica as a

bond, a brick can be procured which will contain as low as 6 per cent or 8 per cent silica.

A high silica content has always been the chief objectionable feature of bauxite brick for basic open-hearth steel furnaces, because the silica is attacked by the basic slag. Authorities on open-hearth practice have generally declared that bauxite brick would be suitable for basic open-hearth furnaces, provided a brick could be made with less than 12 per cent silica content. And, indeed, recent tests made along this line seem to bear out this statement.

A test was made several months ago in one of the basic open-hearth furnaces of the Bethlehem Steel Works, in which a bauxite and a magnesite brick were placed side by side near the gas and air ports, and submitted to the highest temperatures attainable in the furnace. The magnesite brick bent and showed viscosity after a period of 7 minutes against a period of 15 minutes for the bauxite brick. Again, a magnesite brick and bauxite brick were bathed in the slag near the doors for a period of some time, after which they were withdrawn and examined when cold. The magnesite brick was incorporated with slag while the bauxite, when broken open, showed that the slag had not penetrated to its center, but had remained as a coating over the outside. Both bricks were quite badly affected, but it was readily apparent that the bauxite withstood the action of the corrosive slag equally as well as the magnesite.

More recent tests with brick having a lower content of silica have shown up equally as favorable as the magnesite when exposed to the action of the basic slag. The comparison is hard to make in any case, because of the fact that either bauxite or a magnesite brick, if left in the hearth of the furnace for any length of time submerged in the slag, are so violently attacked that the differences in the portions that are taken out are not easily detected. Even a magnesite brick if thrown into a basic open-hearth furnace will be entirely eaten away after considerable length of time, so that the only real test of bauxite brick will be to build a hearth, or portion of hearth, out of these brick and test them, covering them with calcined bauxite and treating them in every way as the magnesite hearths are treated. Some steps are now being taken towards accomplishing tests of this character.

Sir William Siemens found that bauxite was a superior furnace lining, and even though he used an inferior bauxite, containing as much as 35 per cent oxide of iron, he claimed they lasted five or six times as long as the " Stourbridge First Brick." Siemens also says of bauxite: " It is important to observe that bauxite when exposed to intense heat is converted into a solid mass of emery, of such extreme hardness that it can hardly be touched by steel tools, and is capable of resisting mechanical as well as the calorific and chemical action to which it is exposed."

Bischof, in his " Feuerfeste Thone," says that bauxite " when not impure on account of the admixture of foreign substances, especially of iron, which generally occurs in considerable quantities in compounds of aluminum, is extremely refractory." He also goes on to say that " the addition of varieties free from iron, or the white ones, to other refractory clays offers the only important means known of increasing their percentage of alumina, and at the same time their refractoriness."

It appears then that bauxite has been regarded as a refractory material for a long time, but that no definite use has been made of it, also that the inferior grades have been more generally tested than the purer ones.

Aside from its use for open-hearth furnaces, which, by the way, is being thoroughly exploited and investigated to make certain of its fitness before taking any risks, bauxite brick have shown up quite successfully in other lines.

Two recent applications are its uses; first, as a lining for rotary Portland cement kilns, and, second, as a lining for lead refining furnaces.

Lining for Rotary Portland Cement Kilns

As a lining for a rotary Portland cement kiln it has shown unusual durability and has given excellent service. As an experiment, the hot zone (about 10 to 12 feet) of a 60-foot rotary kiln fired with coal dust, was lined with a 6-inch bauxite lining, whereas the kiln had previously been lined with a 9-inch fireclay block.

A block for lining rotary Portland cement kilns in the hot zone must possess the following qualities: It must be neither too hard nor too soft, for if too hard it will not allow the cement coating to stick to the surface, and if too soft it will not hold

the coating, but the latter will pull off, bringing portions of the brick with it. The cement coating affords an excellent protection for the lining, and if brick do not hold this coating they soon burn out. The bauxite block made for this purpose has all of the aforesaid qualities.

After ten months of continuous service, night and day, this 6-inch lining is still doing the work. The loss of output in cement for every 24 hours that one of these rotary kilns is shut down is equivalent to the sum of $250. As the minimum time required for lining or patching a kiln in the hot zone is from 36 to 48 hours, one can easily estimate that the loss of output will be equivalent to a sum varying between $375 and $500. In this case it is quite apparent that a superior lining will be the cheaper in the long run. Again, it must be remembered that only the hot zone need be lined with a bauxite block.

Lead Refining Furnaces

The second and most recent application of bauxite brick has been that of lining portions of lead refining furnaces.

Pig lead, containing copper, antimony and occasionally arsenic and other metals in small quantities, is charged into the hearth of the refining smelter and melted by the reverberation of hot gases from above.

The hearth of the furnace, which is 10 by 13 feet in dimensions, is lined on the bottom by 9-inch square brick set on end. The sides of the furnace are lined with a single course of 9-inch brick and laid with ends against the walls.

The temperature of the furnace is from 1300° to 1400° F., and outside of the part it plays in melting the fluxes bears no relation to the destruction of the brick, as they are sufficiently refractory to withstand much higher temperatures. It is purely a case of chemical action on the brick.

During the process of refining, a scum rises to the surface of the molten lead, and this scum contains most of the impurities which the refining is designed to remove. It consists largely of litharge, or yellow oxide of lead, PbO, copper oxide CuO, and antimony oxide Sb_2O_3, with possibly other oxides in much smaller amounts.

Wherever the brick are exposed to this scum, particularly around the doors, where there is a larger supply of oxygen, and

accordingly litharge is more easily formed, and along the level of this scum, on the walls, they are badly eaten away and have to be taken out after several weeks' service, and generally have to be patched after a week has passed. Consequently, the furnace loses much time for repairs, which lowers its output considerably.

The cutting away of the brick is explained as follows: Multiple silicates are formed between the oxides of the metals in the scum and the silicates of alumina and free silica in the brick, and these are very fusible, because lead oxide, PbO, which is one of the most fusible of the oxides, comprises the greater part of the base or RO element of the silicate. But there are also several other oxides in the base of the silicate, and it is quite well understood that multiple are more fusible than single silicates.

Hence, as very fusible silicates are formed between the scum and the firebrick, the brick are very rapidly decomposed and eaten away. It was observed that a porous brick wore out faster than a dense brick, also that the scum penetrated along the joints for several inches beyond the exposed face of the brick. This was probably due to the fact that the raw fireclay which was used in making the joints is much more soluble in the scum than the burnt clay. Accordingly great care should be taken in laying up the brick to see that the joints are as tight as possible.

Whereas, the scum was composed of highly basic oxides, it was considered reasonable to supplement a basic lining for the firebrick lining, and, accordingly, a lining of bauxite was put in wherever the brick were exposed to the slag. The result was that the bauxite brick lasted from five to six times as long as the firebrick lining.

With the above-mentioned uses and its possible advent into open-hearth practice elsewhere, the writer feels that bauxite brick will at some early future date comprise one of our most valuable and useful refractory materials.

ABSTRACTS *

A NEW Process for Rendering Iron and Steel Non-Corrosive. Sherard Cowper-Coles. "The Iron Trade Review," February 15, 1906. 5,500 w., illustrated. — The author describes the dry galvanizing or "Sherardizing" process for which he claims the following advantages over hot galvanizing:

"There is no waste of zinc dust due to the formation of zinc alloys, consequently the fuel consumed is less. The labor is less, the articles not requiring to be cleaned so carefully as in hot galvanizing. The cost of working is lower, the plant is cheaper, no flux is required, no dross or skimmings are formed as in hot galvanizing, and there is no danger of explosion or breaking of castings and distorting of thin iron work. In dry galvanizing the coating is more uniform than that obtained in hot galvanizing. There is no reduction of tensile strength. The process can be worked intermittently without waste and the work can be placed directly in the pickling bath without drying. Among other applications this process has been applied to case-hardening copper, and the rendering of silver non-tarnishable." **No. 472. A.**

Nickel-Manganese Steels † (Aciers Nickel-Manganese). L. Guillet. "Revue de Métallurgie," November, 1905. — Having completed a general investigation of the ternary steels (alloys

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of iron, carbon and a third element), L. Guillet has taken up the study of the quaternary alloys, starting with nickel-manganese steels. Assuming the possibility of deducing their properties from those of nickel steels and manganese steels, the author gives equations from which the constitution (whether pearlitic, martensitic or containing γ-iron) of a steel of given analysis may be calculated. Three series of alloys were prepared, the first containing 0.15 per cent carbon, nickel 2 per cent, 12 per cent, or 30 per cent, manganese 5 per cent, 7 per cent or 15 per cent; the second containing 0.75 per cent carbon, nickel and manganese both varying as in the first series. The members of the third series have analyses which cause them to be placed on the limit of two groups. Certain of the alloys could not be rolled. As in the author's former researches, the alloys were examined micrographically and mechanically in three states: (1) as forged (or normalized by slow cooling from 900° C.); (2) quenched; (3) annealed. Numerous tables of the results of tensile, shock and hardness tests are given. As in nickel steels, etc., alloys containing γ-iron are transformed by cold working, the γ-iron changing to martensite in a greater or smaller degree. Similar effects result from cooling in liquid air. The author considers that his deductions as to the constitution and properties of these alloys, taking the properties of the nickel steels and the manganese steels as data, are fully borne out by the results of his experimental work. Nickel-manganese steels may for many purposes replace nickel steels. **No. 473. D.**

Corrosion Grooves in Boiler Plates * (Les Sillons de Corrosion dans les Tôles de chaudières à Vapeur). Ch. Frémont and F. Osmond. " Revue de Métallurgie," October, 1905. 5,000 w., illustrated. — The authors point out that the existence of local corrosions in boilers can only be accounted for by irregularities either in original structure or resulting from conditions of construction or service. Corrosions have been classified according to form, (1) in spots (" pustulaire "); (2) in grooves. The former are probably due to original non-homogeneity of the metal, such as inclusions of slag, sulphides, etc. It might be

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* Abstracted in the " Journal of the Royal Microscopical Society," February, 1906.

supposed that the mechanical stresses to which a boiler is subjected when in service cause local strains which lead to irregular oxidation. The authors show how maximum stresses are localized at certain points and lines owing to the method of construction of a boiler. It is along these lines that corrosion grooves are found. The authors advance arguments which tend to show that strain effects in the metal do not account for the grooves. A much more probable explanation is that the plate first becomes covered with a layer of oxide; this oxide is not deformable, *i. e.*, is brittle, and the slight elastic bending of the plate causes the oxide to crack along the line of maximum stress. A clean surface of steel is thus exposed, and oxidation goes on more rapidly. The small corrosion groove thus set up is a line of weakness; stresses are still more localized along it, the reformed oxide is cracked, again exposing a line of bright metal for oxidation. Corrosion grooves are much more dangerous in plates of poor quality than in good material. The authors give an account of the investigations, carried out on four old locomotive boilers, which led to the above conclusions and illustrate their paper with a number of photomicrographs. **No. 474. D.**

Note on Quenching of Steel * (Note sur la trempe de l'acier). M. Demozay. "Revue de Métallurgie," October, 1905. 12,000 w., illustrated. — The author gives a lengthy account of his investigations into the effect upon the hardness of steel and the position of the critical range, caused by varying the conditions of quenching, such as temperature, duration of heating, rapidity of cooling and dimensions of the mass quenched. Hardness was measured by the Brinell method. The critical temperatures were determined by taking cooling and heating curves, the junction of the thermocouple being inserted in a central hole. In the first series of experiments the samples (40 mm. by 10 mm. by 10 mm.) were heated in an electric furnace to the required temperature and quenched. In the second series the steel was heated to a temperature above the critical range, cooled slowly to the required temperature and quenched. Curves showing the relation between quenching temperature and hardness are

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* Abstracted in the "Journal of the Royal Microscopical Society," February, 1906.

given. In the third series the length of time during which the steel had to be maintained at a given temperature to produce the same degree of hardness on quenching was determined. In the experiments upon the effect of variation in the size of the specimen, heating was carried out in a lead bath of large capacity. The steel was quenched in air, in oil or in water. The author gives his conclusions at considerable length. A notable omission from the data given is the analysis of the steels employed in this research. **No. 475. D.**

Mechanical Properties of Single Crystals of Iron * (Les propriétés mécaniques du fer en cristaux isolés). F. Osmond and Ch. Frémont. " Revue de Métallurgie," November, 1905. 4,000 w., illustrated. — The authors obtained some iron in abnormally large crystals, from an old steel rail which had been in use as a guide for a damper in a furnace flue for fifteen years, and had thus been subjected to thermal conditions favorable to the development of crystallization. The metal contained 0.06 per cent carbon. A tensile test piece was obtained, the effective portion of which was constituted almost entirely by two crystals. Two compression test pieces were cut from a single crystal. Stress strain-diagrams are given. Brinell hardness tests were made on different faces of crystal, giving somewhat different results. Statical bending and shock tests showed that the angle made by the cleavage plane with the axis of the test piece had great influence on the results, and that brittleness only appeared under impact. **No. 476. D.**

Foundry Practice. Wm. A. Bole. Paper read before the Pittsburg Foundrymen's Association, February 5, 1906. Abstracted in " The Foundry," March, 1906. 6,000 w. — The paper consists chiefly in the reproduction of a pamphlet issued for the use of the foundry foremen of the Westinghouse Machine Company, and in which the properties of cast iron, the changes taking place on melting, the use of scrap, the requirements of castings, etc., are briefly but clearly described. **No. 477. A.**

The Lelong Process of Chain Making. " The Iron Age," March 8, 1906. 1,100 w., illustrated. — The article describes

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* Abstracted in the " Journal of the Royal Microscopical Society," February, 1906.

an advance in the art of chain making which appears to have been realized in a process patented by Emile Lelong, Brussels, Belgium, by which with one furnace and one machine a continuous chain is made and completely finished. **No. 478. A.**

Gas Producers for Power. Julius Wile. Paper read before the Technology Club, Syracuse, N. Y., February 13. Abstracted in " The Iron Age," March 8, 1906. 4,500 w. **No. 479. A.**

Electricity in the Foundry. H. S. Knowlton. " Cassier's Magazine," March, 1906. 2,000 w., illustrated. **No. 480. B.**

The Briquetting of Iron Ore and the Testing of the Blocks (Die Brikettierung der Eisenerze und die Prufung der Erzziegel). Dr. H. Wedding. " Stahl und Eisen," January 1, 1906. 4,500 w. **No. 481. C.**

Notes on the Cementation Process (Einiges über das Zementieren). A. Ledebur. " Stahl und Eisen," January 15, 1906. 2,000 w. — The author discusses a recent paper of Léon Guillet before the Société des Ingénieurs Civils de France. **No. 482. C.**

METALLURGICAL NOTES AND COMMENTS

William Richard Jones The following excellent biographical sketch of William Richard Jones (see frontispiece) is reproduced in full from " Eminent Engineers," by Dwight Goddard:

" ' The most important man in the Carnegie scheme.' Such is the high praise given to William R. Jones. He was *par excellence* a captain of industry. His father was a clergyman, who came to this country from Wales in 1832, and was located in Pittsburg and Hazleton, Pa. William, his eldest son, was born in 1839. His father died when he was quite young, so that he was forced to begin work with a very limited schooling.

" He was apprenticed to the Crane Iron Company of Catasauqua when only ten years of age, first in the foundry and afterward in the machine shop. No small part of his subsequent success is due to his thorough training in these two fundamental branches of the iron industry.

" By fifteen he was earning journeyman's wages. In 1856, we find him at Philadelphia working as a machinist with I. P. Morris & Co., then in Clearfield County, during a commercial depression, as a lumberman and farm hand. In 1859, he is a machinist in the employ of the Cambria Iron Company; three months later he goes to Chattanooga, Tenn., employed by a blast-furnace company, where he remains until 1861, when, by the breaking out of the Civil War, he is forced to flee with his young bride.

" A year later he enlists in the 133d Pennsylvania Volunteers, is wounded, but rises to the rank of corporal. At the expiration of his enlistment he returns to the Cambria Iron Company, but soon raises a company of men and, as their captain, re-enlists in the 194th Pennsylvania Volunteers, and serves to the close of the war. The latter part of the time he was provost marshal for the city of Baltimore, a position requiring both tact and firmness, and for which services he received honorable mention.

" Then he returns again to Johnstown to be assistant to George Fritz, the chief engineer of the Cambria Iron Company. In this position he is busied in designing and constructing the famous Bessemer plant and bloom mill, under the direction of two of the most brilliant of American mechanical engineers, Alexander L. Holley and George Fritz.

" Following the death of Fritz, Jones resigned from the service of the Cambria Company. So well had he done his work that Holley, who had designed the Edgar Thompson Steel Works at Braddock, selected him to be the master mechanic. Holley was at this time consulting engineer of the Associated Bessemer Manufacturers, and acquainted with all the principal steel men. He looked upon Jones as the best practical administrator among them all.

" Later Jones became the general superintendent, and still later, in 1888, consulting engineer to all the Carnegie companies. In these years he erected their great Bessemer plants, the remarkable series of blast furnaces known as A, B, C, D, E, F and G, and the gigantic rolling mills; he met and overcame all the contingencies of daily operation and intense competition that culminated in making these establishments the finest in the world and a transcendent financial success.

" A dozen patents stand to his credit and all have to do with the manufacture of steel. The first was granted in 1876, a device for operating Bessemer ladles, and the last, in 1889, considered to be the most important, a method for mixing in receiving tanks the metal from blast furnaces.

" But his fame does not rest upon these few patents. Like all mechanical engineers engaged in the practical administration of affairs, he invented and devised far more than he patented. Inventino was to him a necessary incident of daily routine.

" These vast concerns are not born full grown. Engineers' plans are never perfect on first presentation. Errors are to be corrected, omissions supplied, interferences adjusted, methods simplified by incessant watchfulness and practical mechanical judgment.

" There is also a struggle for existence and a survival of the fittest among steel plants as among animals. A comparison of daily reports, a searching of costs, the stimulus of competition, — all compel constant improvement or defeat, and time has shown

that Jones was to be trusted to keep the mechanical equipment of the Carnegie plants ahead of all competitors.

" Here were thousands of men employed, and the selection and management of men measures, in large degree, the success or failure of any enterprise.

" In these things Captain Jones was preëminent. Under his control vast forces were coördinated, warring elements harmonized, selfish interests dominated and the whole organization vitilized, until the production of a single blast furnace went up before his death from 350 tons a week in 1872 to nearly 2,800 tons per week.

" One of the wires to this Carnegie system was rivalry between heads of departments. Rewards were given for record outputs; these were made the standard, and woe betide him who fell short.

" It was competition, bitter and relentless, engendering strife and hard feeling, and yet none dared to let up on the terrible pace.

" Jones was not responsible for this. He was too high-spirited to stand it himself, and when his protests were unheeded, he sent in his resignation again and again, only to be won back: he was too valuable a man to lose.

" ' You can imagine the abounding sense of freedom and relief when I go aboard ship and sail past Sandy Hook,' once said Andrew Carnegie to Captain Jones. ' My God, think of the relief to us ! ' exclaimed Jones.

" When Carnegie offered him a partnership he declined, but accepted ' a thundering big salary,' $50,000 a year, when salaries of $10,000 were few and far between.

" When Carnegie was taken to task by some of the other steel manufacturers for paying such a salary, he responded that he would be glad to pay double if he knew of any more like him.

" Under Jones's management men worked as never before or since. His unerring mechanical judgment, his organizing ability, his unfailing energy, his resistless enthusiasm, won their hearts, and they responded loyally as to a recognized and trusted master.

" In his dealings with them Jones was considerate and sympathetic, at the same time forceful and determined. He attempted an eight-hour day at the Edgar Thompson, but when

it was shown that it was falling slightly behind the others, it was vetoed.

" When called upon to resist extreme demands his opposition was open and above board, so that even in the very fiercest of the conflict he retained the good will of his opponents.

" It was characteristic of him, at the time of the Johnstown flood, to take several hundred workmen from Braddock by special train. The track was destroyed ten miles from Johnstown, but Jones marched the men overland, and was the first outside assistance to reach the scene of destruction. Under his trained direction, they rendered invaluable service in the work of rescue and relief.

" He was a member of the American Institute of Mining Engineers, and, although the leading iron and steel expert of the country, persistently refused to accept office or read papers. He was also a member of the American Society of Mechanical Engineers and of the British Iron and Steel Institute.

" He was a man of considerable property, of stalwart figure and attractive face. His striking portrait shows a remarkable likeness to that of the greatest of Roman commanders, Julius Cæsar, save only the eyes, which belonged to Jones alone, keen, alert, laughing and honest, characteristic of the real man.

" His tragic death was a striking close to such a life. Blast furnace C had been in trouble for several days. The regular organization was unable to bring it under control. Captain Jones assumed personal charge of affairs, and, while directing the work, an explosion occurred in the furnace which caused a rush of gas and molten cinder to fly in all directions. Several men were badly injured, and he was not only horribly burned, but was blown against an iron cinder car, fracturing his skull. He suffered intense agony for two days, and died September 28, 1889.

" In the resolutions offered by the managers of the Carnegie properties, it was said:

" ' We would not forget that the commander fell at the head of his men, at the post of duty, amid the roar of the vast establishment which was his work and is his monument.' "

Growth of Basic Open-Hearth Steel Industry. — One can find no parallel anywhere in the iron trade to the growth of

basic open-hearth steel making in the United States. In 1897, the production by this process first passed the million-ton mark. In 1906, only nine years later, production was 7,815,728 tons. One might suppose that the spectacular advent of the Bessemer steel process would, in its day, have shown a rapid growth like this, but such was not the case, although there were incentives for its development not present with the basic open-hearth industry. The Bessemer process supplanted the cumbersome and laborious process of making wrought iron by the puddling furnace, and offered a vastly better product. The cost of the plant per unit of output was relatively low. An open-hearth steel plant costs several times as much as a Bessemer plant, for the same yearly output.

It was anticipated, early in the development of the basic open-hearth steel process in the United States, that a serious obstacle would be struck, in an inadequate scrap supply, long before production had reached anything like present proportions. The first adoption on a large scale of this process was by the Carnegie Steel Company, with the avowed purpose of finding a good use for the scrap from the Bessemer plants. As the process was expected to use half scrap and half pig iron it is obvious that on such a basis there was no room for production to attain anything like the proportions of the Bessemer steel industry, yet in 1905, the production of basic open-hearth steel constituted about 39 per cent of the total steel production, and at the present rate of growth it may not be more than two or three years until the production of basic open-hearth steel, or at least of basic and acid open-hearth steel together, may exceed that of Bessemer steel.

The industry has reached a point where the tonnage of old scrap material utilized has become almost insignificant. Scrap has been found in unexpected ways. Ingots and partly rolled material are more liberally cropped than formerly, because so good a use for the discarded material is afforded. Scrap is not used as it was, years ago, to cool the Bessemer heat when the silicon was a trifle high. The scrap is saved for the basic open-hearth furnace, and the blast furnace is made to furnish pig iron with only so much silicon as is required for the heat. The Talbot, Monell and other special processes eliminating scrap entirely or reducing the quantity necessary, have helped

greatly. The Jones & Laughlin Steel Company, using the Talbot process, does not need to utilize the scrap produced in the Bessemer department, but has traded large quantities of it with an open-hearth concern which uses the old-style process, receiving billets in return. Its low-phosphorus scrap is sold to steel-casting interests using the acid open-hearth process. The Carnegie Steel Company is a still larger seller of low-phosphorus scrap to such interests.

Additions to basic open-hearth steel capacity continue to be made. One small plant in the south is nearly completed, and two or three more are under discussion. The Illinois Steel Company is completing a plant of seven 50-ton furnaces, having some already in operation. The Follansbee Bros. Company is building a plant of two 25-ton furnaces. The most ambitious project of all is the United States Steel Corporation's plant to be built on the shore of Lake Michigan, in Indiana, just east of Chicago. It will make rails quite largely. The open-hearth plants being built are of all sizes.

A slight index to the relative consumption of scrap in basic open-hearth steel manufacture is obtained by dividing the year's production of basic pig iron by the production of basic open-hearth steel ingots and castings. For 1905 the division comes out 52.5 per cent, which is the largest since 1897, when it was 52.7 per cent. In 1904 it was 48.6 per cent. The minimum was 40.0 per cent, in 1901.

Electric Iron Smelting at the Sault.* — Recent newspaper announcement is to the effect that Dr. Héroult, who has been conducting experiments at the Sault for the Canadian Government in making pig iron by the electric current, has succeeded in producing it at a cost of $10 per ton, "which," the dispatches add, " is a saving of $5, the previous costs having been $15 per ton."

If it is true that pig iron has been produced at $10 a ton, it is a matter of the gravest importance, not only to the future of the iron trade, but to those localities that are long on potential power and raw materials, but short on carbon fuels. Of these Duluth is the most conspicuous example.

It is impossible to get any accurate figures as to costs at

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* " The Iron Age," February 22, 1906.

present.   The experiments are conducted in private and until there is a report to the government, which is represented in the tests by Dr. Haanel, its own superintendent of mines, details as to the amount of energy consumed, the cost per unit, etc., cannot be given.   These are essential to any understanding of the situation, and the newspaper reports that have been sent out from the Sault may be set down as incorrect and premature.   But that there have been important experimental results cannot be doubted.

Dr. P. L. T. Héroult is the technical director of the French electro-metallurgical society; he is a man of great wealth and the proprietor of the aluminum industry of that country.   For years he has been carrying on experiments on the electric reduction of iron ores, for which both his wealth and his previous experience in the production of aluminum eminently fitted him.   He has a number of plants now at work in Europe producing high-grade steels and is continually making improvements by which economy in production is gradually being brought about.   He is thus slowly reaching the point at which pig iron may be made by the electric arc at a price to compete with coke.

PAUL LOUIS TOUSSAINT HEROULT

So far as the experiments at the Sault are concerned it may be stated to-day, semi-officially, that Dr. Héroult has made considerable advances in the way of further economy, since beginning work there a few months ago, and that both he and Dr. Haanal are enthusiastic as to the future of electric smelting of iron ores, where water can be used to generate cheap electric power.   To be sure, Dr. Haanel, at least, does not expect coke furnaces to be driven out, but he does look confidently for the employment of

the electric furnace for special purposes and classes of steels and for its gradual extension into the general field of ore reduction. This is practically all that can be said at this time.

One of the most interesting experiments being carried out at the Sault during these trials is the smelting of roasted pyrrhotite ore (mono-sulphide of iron) directly into a ferro-nickel pig, all the sulphur of the briquettes of pyrrhotite, amounting to 3 per cent, being removed. The treatment of this class of iron sulphides, in distinction from pyrite, has been impossible hitherto. It was in part the costly and unsuccessful attempt to treat pyrrhotites for their sulphur and ferro-nickel, saving the sulphur, that led to the failure of the original Clergue company.

For these Héroult experiments the Dominion government has assisted to the extent of advancing $15,000, which Dr. Héroult expects to return from the income through the sale of licenses in Canada for the use of his electric process. Mr. Clergue and the Lake Superior Corporation granted power and space in their stations, and last October operations on the furnace were begun. These experiments are the direct outcome of the report of the Canadian commission appointed two years ago to investigate the different electro-thermic processes used in Europe for the smelting of iron ores and the making of steels. The commission visited many localities on the continent, especially in France, Sweden and Italy, where the Héroult, the Kjellin, the Stassano and the Keller processes were in operation, and embodied its conclusions in a very technical report published not long ago.

The Héroult furnace, as used here at the Sault, in the big works occupied by the Lake Superior Company's pulp and paper factory, consists of a simple iron box of square cross section, open at the top and lined with dolomitic and other refractory material. The bottom of the casing is provided with a carbon plate, which constitutes one terminal of the electric circuit, the other consisting of a carbon electrode of square cross section placed vertically in the open top of the furnace. There is hand regulation to govern the distance of the electrode within the furnace, and the charge to be reduced is placed between the carbon plate at the floor of the furnace and the vertically adjustable electrode and packed around the latter to the walls of the furnace. The electric current passes between the electrode and

the carbon bottom through the charge, and its energy is absorbed by the resistance of the latter, which is thereby heated to the reduction point. The operation of this furnace is supposed to be continuous and in theory it should not be shut down for anything except repairs or outside causes. To be sure, in the recent experiments, this has not been altogether the case.

It is stated here that the chemical reactions in the electric smelting furnace, as regards the reduction and the combination of iron with silicon, sulphur, phosphorus and other elements, are similar to those in the blast furnace. By altering the burden, regulating the temperature and varying the current any grade of iron suitable for foundry or steels can be produced at will. It is claimed that the change from one grade to another can be made more easily and quickly than in the blast furnace, which, indeed, should be the case, as electric furnaces so far erected have been of small capacity and hand regulated.

Among the conclusions that were given by the Canadian commission above referred to was this: " That pig iron can be produced on a commercial scale to compete with the blast furnace only when electric energy is very cheap and fuel very dear." On the basis of the report, with electric energy at $10 per electric horse-power per year, and coke at $7 per ton, the cost of production is approximately the same in the electric and the blast furnace. The modern blast furnace and the various methods of making steels, as at present employed, are the result of a hundred years of experience and have reached their perfection through many modifications, accepted and introduced, in many cases, only after determined opposition and much hesitation. The process of the electrical reduction of iron ore is yet in the experimental state; in fact no plant exists to-day for the reduction of ore by electricity on a commercial scale. " So," adds the report, " the more remarkable it appears and the more gratifying it is regarding the future of electric smelting, that experiments made so far, and without due preliminaries, so to speak, in furnaces of experimental design, give a figure of costs that would enable the electric furnace to compete with coke in a region where electricity can be had for $10 per electric horse-power year and coke for not less than $7 per ton."

Metals and Their Ferro Alloys.* — At a meeting of the Institution of Mining and Metallurgy in London, on January 18, 1906, a paper was read by Dr. O. J. Steinhart on " Metals and Their Ferro Alloys Used in the Manufacture of Alloy Steels." The author grouped the metals and their ferro alloys used by steel makers in the following order of importance: Manganese, nickel, chrome, tungsten, molybdenum and vanadium and, experimentally, cobalt, titanium, uranium and tantalum. The requirements of steel makers as to the purity of the elements added to steels are very stringent. The consumption and production of nickel is steadily increasing and the output for the present year will be between 13,000 and 14,000 tons. The price ranges between £150 and £185 per ton. The leading Sheffield steel works now control an independent supply of the metal, and the well-known Sudbury district produces more than half the world's output. The total yearly production of ferro chromes is between 4,000 and 5,000 tons, and a suitable ore for the production of ferrochrome should contain at least 50 per cent of Cr_2O_3. Ferrochromes usually contain 6 per cent of carbon, but very pure alloys are made to enable chrome to be employed in low carbon steels. Tungsten has created fresh interest latterly by reason of its application to the manufacture of self-hardening rapid tool steels. The principal ore is wolframite, which in the pure state should contain over 70 per cent WO_3. Prices have varied in an extraordinary manner, but at the present time a 65 per cent ore is worth £85 per ton. The world's production of wolfram ores is about 3,000 tons per annum. Metallic tungsten powder as employed by the steel maker is in the hands of about half a dozen German makers. Molybdenum, belonging to the same group of elements as tungsten, is less reliable and more difficult to prepare in the pure state. Vanadium has come into prominence latterly. The ores used for the manufacture of ferrovanadium contain about 10 per cent of V_2O_5, and such an ore is worth 4 to 5 shillings per kilogram of such contents.

R. A. Hadfield in discussing the paper said that the price of manganese, which once stood at £86 per ton and had fallen to £12, is again going up, and it appeared to him that the price

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of nickel would advance considerably. He hoped prices would not be advanced unnecessarily. Carbon steel might be very largely improved. A number of people who sell alloys have an altogether mistaken notion as to the carbon contents. Nearly all steel requires carbon, and a certain percentage in the alloys is not injurious. For a large number of steels there is no necessity to produce ferrochrome at £15 per ton when chrome alloys can readily be obtained at a much lower price. Nothing has been done seriously as regards the use of tungsten for armor plates, chrome being an element so much cheaper.

The Determination of Chromium in Steel. — The method given below for the determination of chromium in steel, while as accurate, will be found as rapid as and requiring less skill than any other method and is not interfered with by the manganese in the steel. This method is a combination of the methods of Fred. Ibbotson, " Technics," February, 1905, and Harry E. Walters, " Journal of American Chemical Society," December, 1905, with the method of Galbraith, given in Blair's " Chemical Analysis of Iron." I got low results by Ibbotson's and Walter's methods and high results by Galbraith's method. I could not get rid of the permanganate in Galbraith's method, even by boiling a half hour, and the abundant manganese dioxide was difficult to filter. I found no trouble, however, by combining the two methods, and a determination is readily made in three quarters of an hour. I tested the accuracy of the method by adding a standard solution of potassium bichromate to various solutions of steel free from chromium, but containing 0.72 per cent of manganese.

Dissolve 1 to 5 grams of the steel in from 30 to 90 c.c. of dilute sulphuric acid (1 to 4) and add, when dissolved, 3 to 5 grams ammonium persulphate to the lesser amount of steel and 10 grams to the larger amount and heat a few minutes. Add slowly a few small crystals of potassium permanganate, which should be decomposed at once into manganese dioxide. If too much permanganate is added there will be difficulty in filtering. If it is found necessary to add a larger quantity of permanganate than will filter readily, this may be avoided in the next trial by adding more persulphate. After adding the permanganate the liquid should be boiled 15 to 20 minutes to insure the complete destruction of the permanganate. The

liquid is then filtered by suction to remove manganese dioxide, washed with water and a standardized ferrous ammonium sulphate solution added in excess and the excess determined by a standard solution of potassium permanganate. I used a solution of 1 gram permanganate to 1 liter of water and a ferrous ammonium sulphate standard to match.

In testing the accuracy of the method I found 0.03458 gram chromium against the theoretical 0.03452 gram chromium. A check gave 0.03437 gram chromium. Working on 5 grams of steel I found 0.0180 gram chromium against the theoretical 0.01726 gram chromium. This corresponds to 0.36 per cent of chromium against the theoretical 0.345 per cent. Edward Herms, in " Iron Age," February 22, 1906.

Welding Wrought Iron and Steel Pipe by Means of " Thermit." — The Goldschmidt Thermit Company, 47 Exchange Place, New York, have issued a small pamphlet giving detailed instructions for welding wrought iron and steel pipe by utilizing the heat of the thermit reaction, from which the following is extracted:

" The mixture of finely divided aluminum and iron oxide, known by the registered trademark ' Thermit,' when ignited in one spot communicates the combustion throughout its mass without the use of heat or power from outside and produces during this combustion, in about fifteen seconds, a temperature of about 5400° F.

" During the reaction which produces this heat, the aluminum and the oxygen contained in the iron oxide combine to a highly superheated liquid slag — aluminum oxide. The iron, which is set free at the same time and at the same temperature, sinks to the bottom of the containing vessel or crucible.

" By pouring the superheated molten mass around the pieces to be welded, the latter are brought to the necessary temperature and the weld is completed by physical pressure, as described below.

" The ends of the pieces to be welded are filed and then butted carefully together between clamps. Around the joint is placed a cast-iron mold in two parts — the upper one having a narrow gate to admit the superheated mass.

" The thermit is ignited in a flat-bottomed crucible, held

in a pair of tongs. After the reaction the slag fills the upper part of the crucible and has three times the volume of the superheated liquid steel which collects at the bottom when the whole mass is liquified.

"The superheated liquid mass is then poured into the opening of the mold. The slag, flowing first, will adhere in a thin layer to the walls of the mold and the surface of the pieces to be welded and will protect them from contact with the liquid steel which runs in last. On chilling, this layer of slag is easily knocked off. After waiting for the ends to soften, the clamps are drawn up and effect the weld by squeezing together the now plastic ends of the parts to be welded.

"The welded pieces are as strong at the joint as elsewhere. After removing molds and clamps, the weld is perfectly solid and there is only a barely perceptible upset at the joint, which can be machined off if desired.

"The process provides a means of joining anywhere *in situ*, without machinery, furnace, electric power or hammering, and is used for welding tubes for steam pressure, tubes for deep well lining, tubes for hydraulic work, tubes for compressed air, tubes for ammonia (gas or liquid), Shelby tubes, rods of rectangular or circular section for reinforced concrete and various other purposes.

"The method has great value for welding pipe coils of one piece. The welds can be made before or after the pipes are bent."

Steel Ties of the Future.* — An increasing number of the large railroad systems are experimenting with the steel tie. The large steel producers, moreover, have been doing some experimenting of their own, not only towards the establishment of the fact that metal ties are practical, but also towards the production of a shape that is the best and the most economical. The largest producer in the Pittsburg district has attained to a shape which it thinks fills all requirements and is now offering the same to the railroads for purposes of experimentation. The general adoption of steel cross ties would constitute a new and important branch of the steel trade and for that reason the probabilities of its adoption has general interest. This tie in question is an H-shaped product except that the top flange is only $4\frac{1}{2}$

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* " The Iron and Machinery World," February 17, 1906.

inches wide, whereas the bottom flange is 8 inches wide, the depth being $5\frac{1}{2}$ inches. The weight per tie is about 170 pounds and the selling price for experimental purposes about $2 each. About 2,200 are required to a mile of track, the tonnage required for equipping a mile of track being about 170. To equip the 210,000 or more miles of main track in the United States would, therefore, require over 35,000,000 tons of these cross ties. The market in prospect is, therefore, vast. Side tracks and electric lines would materially increase the tonnage needed, to say nothing of future extensions and renewal requirements.

It is maintained from experiments already made that the cost of the use of these steel ties will be less to the railroad companies than that of wood ties. The life of the latter is from three to seven years. The life of the steel rail is estimated at twenty to thirty years. It is stated by railroad people that it costs them two and a half times more to maintain the ties in their track than to maintain the steel rails. There are some metal ties in use in Pennsylvania, a hollow trough pattern of German origin, that have been in use for twenty years and some of the more modern ties have been down for six years without showing evidences of especial depreciation. The same influences that keep the steel rail from rusting, it is stated, preserve the steel cross tie, so that no painting or surface preparation is needed. The disconnection steel rail, as every one knows, quickly rusts, but the rail in use preserves its color and freedom from oxidation, the immediate cause being the extreme vibrations of the passing trains. The same influences save the cross tie in place. Moreover, when the metal cross tie is finally discarded it may be sold as scrap for a considerable percentage of its original cost, whereas the discarded wooden tie is valueless. The wood tie costs to-day from thirty to ninety cents each, according to grade and district, and from the recent trend of values, dollar ties will soon be common. On the other hand, there is the possibility that the steel tie may decrease in value. All conditions seem to be pointing to the early appearance of the steel tie as a marketable product.

American Institute of Mining Engineers. — The ninetieth meeting of the American Institute of Mining Engineers was held at Lehigh University, South Bethlehem, Pa., on February

21–24, 1906. The secretary announced that Robert W. Hunt, of Chicago, had been elected president for the succeeding year, and that Dr. James Douglass, of New York had been elected an honorary member. The following papers pertaining to the iron and steel industry were read and discussed: " A Discussion of James Gayley's paper on ' The Application of Dry-Air Blast to the Manufacture of Iron ' "; discussed by Prof. H. M. Howe and J. W. Richards, Dr. R. Raymond and James Gayley. " Piping in Steel Ingots," by N. Lilienberg; discussed by Prof. H. M. Howe and J. W. Richards.

ROBERT W. HUNT
President-elect American Institute of Mining
Engineers

Blast-Furnace Charging Apparatus.* — A device for charging blast furnaces has been so designed that the contents of the hopper may be directed toward the sides of the furnace or may be divided into two streams, one flowing toward the middle of the furnace and the other toward the sides. The inventor is Gibbon C. Shackleford, Allegheny, Pa. Fig. 1 is a sectional elevation of the upper portion of a blast furnace, showing the arrangement of the charging apparatus. In Fig. 2 the bell is shown as lowered. There is the usual hopper *a*, with its lower sides *b* converging and having a central discharge opening. The opening is closed by the bell *c*, which is of the usual shape and construction and fits closely into the opening in the hopper. The distributing bell *d* has its upper end cut away so as to form an opening into which the main bell will fit, closing the opening in the distributing bell. The edges of the opening in the upper end of the distributing bell rest upon a seat *e*, formed in the periphery of the main bell, the opening in the distributing bell being at least equal to the opening of the discharge hopper.

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* " The Iron Age," February 8, 1906.

The main bell is connected by a rod f to the bell-operating mechanism. The distributing bell d is similarly connected by rods g to a raising-and-lowering mechanism independent of it, which operates the main bell.

If it is desired that the charge be deposited in the middle of the furnace the main bell is lowered, as shown by dotted lines
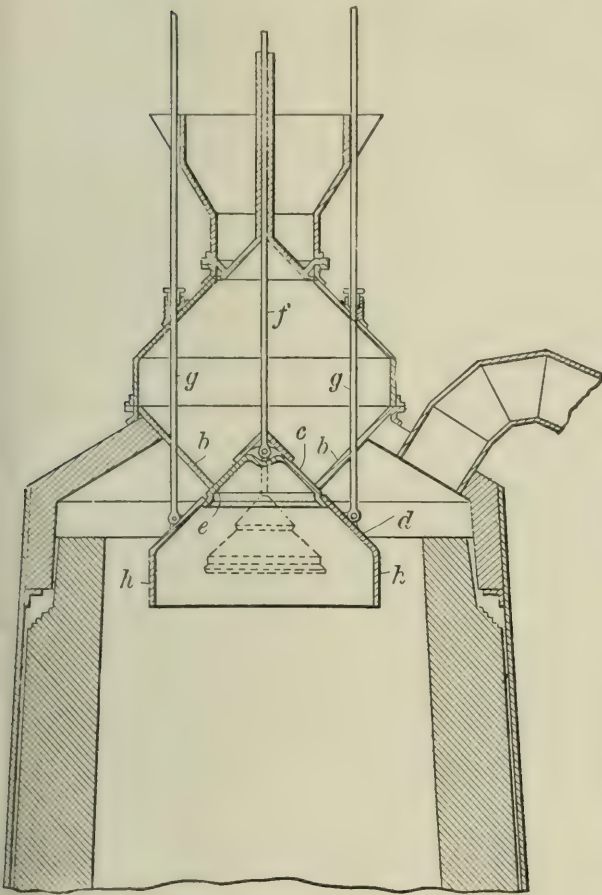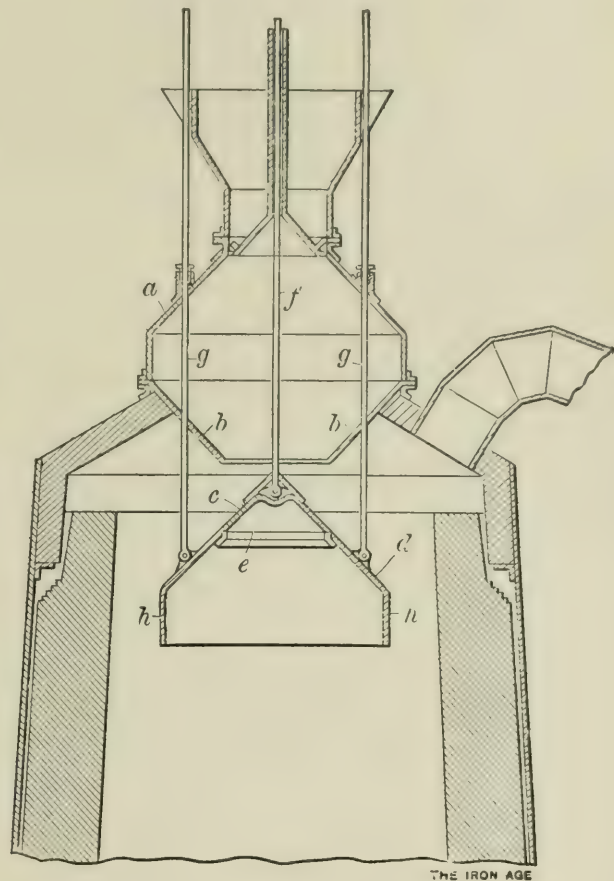
Fig. 1.   Fig. 2.

Blast-Furnace Charging Apparatus

in Fig. 1, so that the entire contents of the hopper will pass down through the opening in the hopper and also through the distributing bell. As the charge strikes against the lowered bell it is thrown outwardly, but the outward movement will be checked by the curtain wall h on the lower end of the distributing bell, and thus the charge will be directed in straight lines to the middle of the furnace. On the other hand, if it is desired to direct the contents of the hopper to the sides of the furnace, both bells are

lowered simultaneously, as in Fig. 2, and the contents of the hopper are directed by the sloping sides of the two bells to the sides of the furnace. It will be noted that the main bell *c* is the sole means of closing the hopper.

A Low-Resistance Thermo-Electric Pyrometer and Compensator. — At a recent meeting of the American Society of Mechanical Engineers, Prof. W. H. Bristol described a thermo-electric pyrometer which he has recently devised. The following is abstracted from a review of his paper published in " The American Machinist," February 8, 1906:

" Professor Bristol began by saying that for a good many industrial purposes the temperatures employed range from 2000° F. downward. For such temperatures the durability and reliability of his instrument had been demonstrated, and while he considered it applicable to higher temperatures, he would not speak with assurance of such applications. He described the work of others in this field, referring more especially to the Chatelier pyrometer, with which he contrasted his own. The Chatelier is essentially a high-resistance and hence delicate instrument. The thermo-couple is composed of platinum and platinum alloy, making it expensive, while the current being feeble, the galvanometer needle must have a filament suspension, making it a delicate instrument. Moreover, it must be permanently and substantially mounted. In the speaker's instrument the couple is composed of various combinations of tungsten, steel, nickel, iron and copper, the combination used depending on the scale of temperature to be covered. The entire apparatus, including the recording instrument, is of low resistance, the current being comparatively heavy and making it practicable to use substantial jeweled pivot bearings in the recording instrument, which is, in fact, of the Weston type and may be hung anywhere or may be encased in a box for portability. No rare metals being used in the couples, they are of low cost and substantial size, and may be used in large numbers, the couples being inserted in various parts of the furnace and connected by switches to a common recording instrument. In this connection diagrams of nineteen couples inserted in various places in boiler flues were shown and in connection therewith diagrams showing the progressive fall of temperature were exhibited. The couples are made in sections so that the end exposed to the high tem-

perature may be renewed when necessary, at slight expense. The entire couple is of such length as to reach to the floor, where it is influenced but little by the heat of the furnace. The insulation of the couple is by asbestos and carborundum paint and is thus both cheap and free from danger of accident. The sensitiveness may be indefinitely increased by joining couples in series, a striking exhibition being made of such an instrument, which responded promptly and decisively to the warmth of the hand.

"When used for determining the temperature of melted metals, — as, for instance, a lead bath, — the hot ends are not joined, the electric connection being made by the melted metal. This use of the instrument has many applications; for example, to hardening steel and to determining the temperature of melted brass and bronze.

"The readings of the instrument give the difference in temperature between the hot and the cold ends, which latter cannot well be kept constant, and a beautiful compensating device has been provided to offset the effect of varying temperatures of the cold end. This consists of a thermometer bulb with a short and comparatively large tube, in which is a loop of platinum wire, the lower end of which dips in the mercury. This is placed in proximity to the cold end of the couple, where it has the same temperature. As the temperature rises the mercury rises in the tube with it and thus short-circuits a portion of the platinum loop and cuts its resistance out of the circuit and *vice versa*. The compensation is exact for any one temperature which may be chosen and approximate for other temperatures.

"In addition to the advantages of the low-resistance type of instruments that have been given are the further advantages that they permit the use of dead-beat recording instruments, making the reading almost instantaneous, whereas with the high-resistance type each change of temperature leads to oscillation of the needle, which must be allowed to come to rest before readings are taken, and that by varying the resistance in circuit the same couple may be used for different ranges of temperature. Moreover, the compensator is possible with this instrument only."

Open-Hearth Practice Getting the Preference.* — The exhaustive report of the special committee on steel rails, presented

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* "The Iron Age," February 8, 1905.

at the recent annual meeting of the American Society of Civil Engineers, which recommended revised specifications for Bessemer and open-hearth sections, only briefly touched upon the relative merits of rails manufactured from these two kinds of steel, but the conclusions reached after studying the results obtained from basic rails point to their giving better service than those rolled of Bessemer steel.

Widespread interest has been manifested by railroad engineers in the introduction of the basic product by the Tennessee Coal, Iron and Railroad Company, and the Bessemer rail makers with great investments at stake in manufacturing and ore properties have displayed the keenest interest in the experiments carried on by many roads throughout the country where the rails have been laid side by side to ascertain their relative wearing qualities. While it is true that the use of the basic rail in this country has extended over only a comparatively short period,— too brief, in fact, to arrive at any definite conclusions, — nevertheless, the investigation of this committee is of the utmost importance and value and the report on the subject follows:

"Your committee has studied the results obtained from basic open-hearth steel rails, and while their use has not extended over many years, at the same time the evidences point to their giving better service than the Bessemer rails. This is strikingly demonstrated by certain experimental very high carbon ones laid on the lines of the Pennsylvania Railroad. It must be understood that the physical differences of the two steels are not entirely due to their chemical composition, as it is a well-known metallurgical fact that steel made by the basic open-hearth process possesses characteristics of its own."

Notwithstanding the comparatively limited distribution of open-hearth rails on roads throughout the country, northern rail makers realize that the tendency is strongly toward the extended use of the basic section from the glowing reports received from maintenance of way departments making experiments along this line, and the report of this special committee only strengthens the conclusions reached some time ago by those in close touch with the situation.

That the United States Steel Corporation has decided to erect a rail mill at its new plant near Chicago, where steel opera-

tions will be limited to basic practice entirely, indicates its recognition of this new factor in the steel trade. The large investments represented in the Bessemer works from which the rail mills in the North derive their steel supply, to say nothing of the Bessemer ore holdings which eliminate other processes, make the adoption of the basic practice at these plants not only improbable but impossible. The development of the basic rail in the South was the only solution of the manufacture of this product in that section of the country, on account of the nature of the ore to be had. In the North, however, the abundance of Bessemer ores in the Lake Superior region, together with the uncertainties of practice in the open hearth when most of the northern rail mills were built, naturally led the way to the use of steel made by the pneumatic process.

The preference of other steel users for open-hearth material, which is becoming more insistent every day, was clearly manifested during the depression in 1904, when open-hearth works for the most part were operated at their capacity, while the Bessemer plants were largely idle. During periods of great activity, such as the present, when consumers despite their preferences will accept steel of either grade, the consumption of both is limited only by the productive capacity. That only one Bessemer plant is included in the large number of steel works projected and under way shows the producers' full appreciation of consumers' demands and the necessity of meeting changing conditions.

Export Duty on Swedish Iron Ore.*— The prospects are that within the near future the Swedish government will place an export duty on iron ore. The matter came up last May, and was defeated in the Swedish parliament by a very narrow margin. It is up again, and with more insistence, but immediate action is delayed by the fact that the upper house is wrestling with the problem of a duty graduated according to the amount of metallic iron contained in the ore, with rebates for particularly undesirable impurities, titanium, sulphur and phosphorus, while the lower house is concerned with the matter of establishing an increasing duty each year until a maximum is reached. The proposed maximum is three kronor — a trifle over eighty cents —

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* "Iron Trade Review," March 1, 1906.

per gross ton.   Meanwhile it is proposed to levy a nominal duty amounting to about five cents per ton, and strenuous opposition has already appeared in Germany and Great Britain.   The Germans propose reprisals, having a flexible tariff arrangement, while the British feel that the Swedish government should be grateful to England for the prospect that the British export duty on coal will be abolished.

Swedish exports of iron ore amounted to 3,677,841 metric tons in 1903 and 4,084,647 metric tons in 1904, according to official figures.   More than three fourths of the tonnage went to Germany, but England is using increasing quantities of Swedish ore.

The Swedish production of pig iron is relatively insignificant.   It is claimed in some quarters that the Swedish magnetic ores cannot be well used except with non-magnetic ores, but the Swedish government either thinks differently or concludes that it is better to make something out of the exportation of the ores. if they cannot be used at home.

Unofficial estimates of Swedish pig-iron production in 1905 place the total at 527,300 metric tons, or 518,967 gross tons, and the total is compared with a similar estimate for 1904, by which a gain of 7,000 tons is shown.   As a matter of fact, however, official figures for 1904 are available, and show a production less than the estimate, or 520,173 gross tons, so that there would really be indicated a decline of 1,206 gross tons.

The provisional returns of Swedish pig-iron production in 1905 can be added to other statistics already collected, and make the world's pig-iron production in 1905 as follows, in gross tons, the tonnage of " other countres " being taken as unchanged from 1904.

WORLD'S PIG-IRON PRODUCTION, 1905

	Gross Tons
United States	22,992,380
Germany	10,813,983
Great Britain	9,592,737
Belgium	1,329,109
Sweden	518,967
Canada	468,003
Other countries	7,825,662
Total	53,540,841
1904	44,883,295
1900	40,173,915
1890	26,980,810

For 1905 the figures for the United States and Canada are official; for England they are those of the British Iron Trade Association, which may be modified slightly later on by the board of trade returns, while the figures for Germany, Belgium and Sweden are provisional.

The Steel Industry of Nova Scotia in 1905.* — United States Consul West, of Sydney, Nova Scotia, gives data concerning the operations of the Dominion Iron and Steel Company and the Nova Scotia Steel and Coal Company, Limited, in 1905. The statistics he gives will serve to set right some misapprehension as to the amount of iron ore imported by the Dominion Iron and Steel Company. The company shipped for its own use from its mines in Newfoundland, 380,254 tons, while the ores imported from the United States, Spain and Sweden amounted to 28,952 tons. The limestone and dolomite shipments from Cape Breton aggregated 267,237 tons. The output of pig iron was 162,000 tons and of steel 163,500 tons. Of 80-pound steel rails the total rolled between June and the end of the year was 44,000 tons and the output of rods in the year was 47,000 tons. The balance of the steel produced went into blooms and ingots, most of which found a market in Canada. A shipment of 30 tons of rails was made to the Boston Elevated Railway Company for experimental use on the sharp curves of that road, the purpose being to find out to what extent the open-hearth rails exceed in wearing qualities the rails heretofore in use. Referring to the Nova Scotia Steel and Coal Company, Limited, Mr. West gives the output of coke at 120,000 tons, pig iron 58,000 tons, steel 22,000 tons. The importations of ore from the company's mines in Newfoundland were about 100,000 tons and from other countries 15,000 tons. Pig iron and steel ingots are shipped to the company's works at Trenton, Nova Scotia, and to various Canadian markets. The shipments of bituminous coal in 1905 from the mines of the Dominion and Nova Scotia steel companies amounted to 3,158,907 tons.

Bessemer Memorial Fund. — A circular has been issued by Mr. C. McDermid, honorary secretary of the Bessemer Memorial Fund, from which the following is extracted:

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* "The Iron Age," February 22, 1906.

" On June 29, 1903, a meeting was held at the Mansion House, under the presidency of the Lord Mayor (Sir Marcus Samuel, Bart.), to inaugurate a memorial to the late Sir Henry Bessemer   At that meeting the following resolution was moved by the Duke of Norfolk, seconded by Prof. H. M. Howe, of Columbia University, New York, and unanimously adopted:

" ' That this representative meeting heartily indorses the proposal to commemorate the great achievements of the late Sir Henry Bessemer, the inventor of the metallurgical process which bears his name; and it strongly affirms that such commemoration should have for its object some educational work as far-reaching in its beneficent influence as are the results of Bessemer's great invention.'

" In April, 1904, the president of the board of education appointed a departmental committee to inquire into the working of the Royal College of Science and Royal School of Mines, in connection with other existing or projected institutions for teaching of the same kind. It was, therefore, necessary for the Memorial Committee to defer the active prosecution of their scheme pending the decision of the Government Committee in regard to the position and future organization of the Royal School of Mines, with which the memorial is to be united. The Departmental Committee having presented their final report, the Memorial Committee are now in a position to take the necessary steps to carry out their proposals.

" We are confident that no memorial could be more appropriate than one which has for its object the scientific advancement of the great metallurgical and mining industries upon which the prosperity of the British Empire so largely depends; and we are also assured that none would be more likely to have met with Bessemer's warm approval or more likely to inspire students to emulate his example of untiring effort for the advancement of industrial methods and processes. It is not necessary to dwell on the magnitude of the benefits that have accrued to mankind as the direct and indirect result of Bessemer's achievements. We, therefore, appeal with confidence to the industrial and general public for their generous support to the Memorial Fund, the objects of which are:

" (*a*) The establishment of open international memorial scholarships for post-graduate practical work, tenable (except

such as it is intended to allocate to the Royal School of Mines, the Sheffield and Birmingham universities, the Armstrong College, Newcastle-upon-Tyne, or other approved British institutions) in any part of the British Empire, in the United States of America and in Europe. It is intended that these scholarships shall be of such value and shall be awarded under such conditions that they will be regarded by students of any nation as a prize worth striving for, and as an incentive to the highest scientific attainment.

" (*b*) The equipment of mining and metallurgical memorial laboratories in the Royal School of Mines at South Kensington as the center of the memorial. (NOTE. — The land and the cost of the new buildings and maintenance for the school will be provided from government and other sources.)

" (*c*) The erection of a statue of Bessemer in the new Royal School of Mines at South Kensington.

" It is hoped that the movement may commend itself to the citizens of all nations who have benefited materially by Bessemer's work. Communications should be addressed to the Honorary Secretary, Bessemer Memorial Fund, Salisbury House, E. C., and all cheques should be made payable to the ' Bessemer Memorial Fund,' and crossed ' Bank of England.' Formal receipts will be issued in respect of all contributions received, and a list of these will be published in due course.

" Subscriptions (amounting to about £8,000) towards the very considerable sum that will be required, have been already received or promised."

John Fritz Medal for Mr. Westinghouse.* — The second award of the John Fritz medal has been made to Mr. George Westinghouse by the following board selected for the purpose: From the membership of the American Society of Civil Engineers, Alfred Noble, Charles Warren Hunt, Charles Hermany and C. C. Schneider; from the membership of the American Institute of Mining Engineers, James Douglas, Charles Kirchhoff, E. E. Olcott and E. G. Spilsbury; from the membership of the American Society of Mechanical Engineers, Robert W. Hunt, S. T. Wellman, James M. Dodge and John E. Sweet; from the membership of the American Institute of Electrical Engineers, Charles

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* " Railway and Engineering Review," January 27, 1906.

P. Steinmetz, Charles F. Scott, B. J. Arnold and John W. Lieb, Jr. The medal is of gold, about of $100 value, and with it is presented a certificate of the award. The medal was awarded to Mr. Westinghouse for " the invention and development of the air brake."

Oil Engines in Steel Works. — The largest order ever placed for oil engines has recently been awarded to the De La Vergne Machine Company, of New York, by Burnham, Williams & Co. (Baldwin Locomotive Works), Philadelphia, Pa. This is for engines aggregating over 3,300 actual horse-power. Some of these are to be installed in Philadelphia, and the remainder at their steel works, at Burnham, Pa. The installation will consist of 125 and 230 horse-power " Hornsby-Akroyd " oil engines, and they are to be used for direct connection to electric generators and to air compressors, while others will be used for operating machine tools by belt.

The manufacturers claim that with these engines and with crude or fuel oil at two cents a gallon, the cost of operation is one-quarter cent per actual horse-power per hour.

Workingmen's Insurance and Employers' Liability. — The following circular has been received from the Department of Commerce and Labor, Bureau of Labor, under date of February 10, 1906:

" The Bureau of Labor is preparing a report covering the various systems of workingmen's insurance and employers' liability both in this country and abroad. The report will cover insurance against sickness, accident, disability, old age, death and unemployment.

" In this connection it is endeavoring to secure information concerning the existence in the United States of what are usually known as establishment funds — that is, mutual relief or insurance funds organized and maintained by the employees of an industrial establishment, or relief funds supported either wholly or in part by the employers themselves. It is desired to obtain, wherever possible, copies of constitutions, rules and by-laws, blank certificate forms and any other matter relating to funds of this character. In the absence of other data the name and location of establishments in which such funds exist are desired.

" In view of the wide circulation which your journal has among employers of labor and others who may be in a position to furnish information regarding this subject, I would esteem it a great favor if you would insert in an early issue of the same a brief mention of the above facts, with the request that persons possessing data of any kind relative to the existence of establishment funds in this country communicate with me at their earliest convenience."

Autogenous Welding.* — The art of welding is doubtless as old as the use of iron in the arts, and its development, from the manipulation of pieces within the limits of human strength at the blacksmith's forge, to the massive productions of the steam hammer and the hydraulic forging press its operations are well known. Within the past few years, however, there has been developed a series of methods of autogenous welding, or union of pieces by the fusion of a portion of their own substance, using gas fuel, and gradually progressing from the direct use of gas burners to the employment of the oxy-hydrogen blowpipe and more recently of the oxy-acetylene blowpipe. In a paper recently presented by Herr E. Wiss before the Verein Deutscher Ingenieure, and published in the " Zeitschrift " of the society, the present state of the art of autogenous welding is discussed, with interesting examples of the manner in which what was formerly a curious laboratory experiment has become an every-day manufacturing operation.

The use of water gas for welding has already been extensively employed, the gas being taken from a holder and compressed mechanically for delivery to the burner, the air supply being controlled so as to be somewhat less than the quantity required for theoretically complete combustion in order to avoid oxidation of the metal at the welded seam. Joints thus made have shown satisfactory results, the tested strength of the seam reaching 99 per cent of the solid material, but the size and cost of the plant required limits the application of the method to establishments in which the conditions of work warrant the outlay. Apart from the character of the apparatus, it has been found by experience that the water-gas system is impracticable for sheet metal below about 8 millimeters in thickness, although it has

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* " Engineering Magazine," March, 1906.

been employed to advantage for sheet iron or steel from 8 millimeters up to 50 millimeters thick.

After briefly reviewing the processes of electric welding, including both the arc and the resistance methods, Herr Wiss proceeds to discuss the application of the blowpipe with mixed gases. Considering first the oxy-hydrogen blowpipe, Herr Wiss examines and compares the theoretical and practical conditions. The combustion of two parts of hydrogen with one part of oxygen should generate theoretically a temperature of 6700° C., but by the dissociation of the vapor of water this temperature falls to 2400° C. By an examination of the temperature of a mass of magnesite exposed to the action of an oxy-hydrogen blowpipe, using the Wanner optical pyrometer, Herr Wiss finds that a temperature of 2100 is actually attained. The difference is accounted for partly by the inability of the pyrometer to perceive the maximum temperature and partly to losses by radiation.

The ability to produce high temperatures by use of the oxy-hydrogen blowpipe has been known for a long time, and the principal impediment to the use of the apparatus in the arts has been the high cost of the process. It is only with the introduction of modern processes for the economical manufacture of the gases that the method has come into use in the industrial arts, but there is every reason to believe that present facilities will lead to its extended use.

Two methods are, at present, in use for the production of oxygen for commercial and industrial purposes. One of these depends upon the electrolytic decomposition of water for the production of both the oxygen and the hydrogen. The other remains as about the only really commercially valuable application of the production of liquid air, and depends upon the fractional distillation of this interesting liquid for the separation of the oxygen from the nitrogen in form for practical use.

In practical work it is found that more than the theoretical proportion is needed, and hence the ordinary decomposition of water, while furnishing the theoretically correct proportions of oxygen and hydrogen, is not altogether sufficient. At the same time it is found that, in the ordinary operations of chemical industry large volumes of hydrogen are released, and this may be isolated, as a by-product, and placed at the disposal of the engineer.

The production of oxygen by the fractional distillation of liquid air has already been discussed in these columns, and it is now conducted on a commercial scale in various countries. In Germany the undertakers of the Linde process are prepared to furnish oxygen of 95 per cent purity at a price of 4.5 pfennigs per cubic meter; at the rate of 100 cubic meters per hour and allowing 12 pfennigs for the cost of compression, it seems that the present selling price of 2.5 marks per cubic meter should be reduced very materially before long, since the manufacturing cost is about 20 to 25 pfennigs, including everything.

In practice the oxygen and hydrogen are used from receivers in which the gases are compressed to 125 to 150 atmospheres. In this connection Herr Wiss calls attention to the objectionable practice of lubricating the oxygen compressors with oil or glycerine, this permitting the presence of hydrocarbon vapors, which, at the temperatures of compression, may lead to ignition and explosion. Compressors used for oxygen should be lubricated only with water, which answers every purpose. There is no objection to the lubrication of hydrogen compressors with hydrocarbons, providing the lubricant is prevented from passing into the flasks in which the compressed gas is stored.

Formerly the gases were consumed in the type of burner devised by Daniel, in which the gases were not mixed until the moment of combustion, but it has been found that a higher temperature is obtained if opportunity is given for a more intimate mixture than is thus possible. Present practice provides a mixing nozzle with a chamber beyond, from which the gases are delivered to the burner point, this latter having various sized tips provided, according to the nature of the work.

The rate of combustion is dependent upon the proportion of oxygen present. When the theoretical mixture of two parts of hydrogen to one of oxygen is reached, there is apt to be a succession of little explosions, and in practice it is found that the best proportion is four to five parts of hydrogen to one of oxygen, this also preventing the formation of a flame which will oxidize the metallic surfaces under operation.

Herr Wiss illustrates and describes the methods of using the blowpipe for the welding of structures of sheet metal of various irregular forms, and shows the ease with which the apparatus can be used, even upon material down to 3 millimeters in thickness. For complicated pieces especially, the method is

more economical than other methods of working, besides which the finished piece has the advantage of being entirely seamless and with the strength of the metal in all parts practically unimpaired.

The use of acetylene in place of hydrogen is discussed in the paper, with especial reference to the application of the Fouché process of storing acetylene gas under pressure in an absorbent material charged with acetone. Since the heating value of acetylene is materially higher than that of hydrogen, a higher temperature may be produced by this apparatus than with the oxy-hydrogen blowpipe. It has been computed that the temperature in the oxy-acetylene burner approximates 3600° C., but Herr Wiss states that an examination with the Wanner pyrometer shows the highest temperatures attained in practice to be about 2340° C., as compared with 2100 C. for the oxy-hydrogen blowpipe. Since 1900 degrees is ample for the welding of wrought-iron plate, the higher temperature appears unnecessary, and possibly injurious, so that there is no necessity for using acetylene where hydrogen is found amply effective.

The paper of Herr Wiss contains much useful information about a process which has already found many valuable applications, and which, with impending reductions in the price of oxygen, bids fair to become a standard appliance in the operative machine shop.

Steel Rail Exports.* — It was presumed to be a part of the international arrangement of steel rail manufacturers, entered into last year, that the mills in the United States were given the American continent (excepting Canada) and adjacent islands as exclusive export territory. If this be the case the indications are that they were well compensated for the surrender of any export opportunities they might have in the more distant countries. The South American trade has been greater than has been generally appreciated and, from what has come to the attention of domestic rail manufacturers, plans already on foot for further railroad building in the countries to the south of us will result in large orders in the next few years. Argentina, Chile and Brazil are in the midst of a campaign of development that has large promise for the future of all three. Railroad

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* " The Iron Age," February 22, 1906.

building must precede the conversion of splendid resources —
agricultural, timber and mineral — into an active production
of wealth on a scale only suggested by the industrial operations
thus far carried on. Capital from the United States has been
going into South America and much more is to follow.

It will be of interest in this connection to note the destina-
tion of the steel rails exported from the United States in the
past three years, particularly in view of what is suggested as
to the future scale of operations of the rail manufacturers of the
United States in the outside fields which are naturally theirs:

EXPORTS OF STEEL RAILS FROM THE UNITED STATES, 1903–1905

	1903 Tons	1904 Tons	1905 Tons
Europe	1,070	17,581	17,625
British America	21,249	216,805	24,450
Central American States and British Honduras	1,229	7,836	12,186
Mexico	2,154	23,871	55,682
West Indies and Bermuda	1,376	15,557	31,168
South America	778	28,347	124,632
Japan	1,000	28,992	10,515
Other Asia and Oceanica	1,800	72,746	15,081
British Africa	....	1,355	3,684
All other Africa	....	1,755	....
Total	30,656	414,845	295,023

The exports of 1903 are really negligible, since they are more
than three times offset by imports amounting to 96,039 tons,
while the home production made a new record of 2,946,756 tons.
But it is to be noted how large a percentage of the rail exports
of these three years went to countries in the Western Hemisphere
— 87 per cent in 1903, 70 per cent in 1904 and 84 per cent in
1905. The exports to British North America in 1904 rose to
216,805 tons, due to the large deliveries of rails to Canada in
anticipation of the duty that became effective November 1
for the protection of Canadian rail mills. The significant factor
in the table is 124,632 tons, representing the exports to South
America in 1905. Mexico, the West Indies and even the Central
American States made noteworthy demands upon our rail mills
last year, and the export total is a remarkable one when the
large home consumption is considered. The exports of 295,023
tons are considerably in excess of the average rail exports of

the ten years preceding 1904 — 157,362 tons — on which the percentage of export rails allotted to the United States in the international rail agreement is said to have been based.

Central America has only made a beginning in railroad construction, and Mexico has prospective requirements in rails, with which her single rail mill thus far gives little promise of coping. But South America seems on the eve of a development that will mean much, saying nothing of the proposal for an all-rail route from the United States to the farthermost countries on the south, which the Government at Washington investigated through a special commissioner in 1904. It will be many years before an iron industry can be built up in South America, even though the ores found in some parts of the country can be supplemented by available coal, which is not the case to-day. Under these conditions the iron trade of the United States should find for all lines of finished products an outlet to the south which with the completion of the Panama Canal would become no inconsiderable factor in this country's outer trade.

REVIEW OF THE IRON AND STEEL MARKET

March has been even duller than February as to new buying in iron and steel, but production has continued at a heavy rate, probably a trifle heavier than in February. The furnaces and mills are well supplied with business and need not be concerned should a fresh wave of buying not come before May, by which time it is confidently expected.

There has been continued buying of rails, and the mills are sold up until nearly the end of the year. Production bids fair to exceed the remarkable record made in 1905, when about 3,300,000 tons of all kinds of rails were produced, an increase of more than 300,000 tons over the best previous record. A similar gain may be made in 1906.

Structural business has continued good and mills are as far sold up as they have been at any time, although productive capacity has increased.

Price changes have not been very important. The leading interest on the 20th announced its price on sheet bars for the second quarter, on quarterly contracts, at $2.00 advance, the billet market being unchanged. Common iron bars have slumped in all markets during the past two months, while most of the decline in the Pittsburg market has occurred since our last report, the market dropping from 1.85 to 1.65 cents, delivered Pittsburg. Early in March scrap declined further, but in the second half of the month some good sales of heavy melting stock were made and the market on this grade became much steadier.

The cotton tie price for the season has been fixed at 85 cents per bundle, f. o. b. Pittsburg, the same as last year. The prospective consumption is estimated at 1,750,000 bundles, weighing 45 pounds per bundle with buckles.

Pig Iron. — Sales of all grades were light during March. The Steel Corporation bought about 8,000 tons of Bessemer for March and April delivery at $17.25, valley, and 5,000 tons of basic at $17.00, valley. Sales of Bessemer to other interests

have been made at $17.50, valley, the largest tonnage taken being 3,000 tons. Larger lots could have been had at $17.25, as would probably be the case now. Bessemer iron has been stronger than other grades, as the merchant furnaces in general are but indifferently supplied with Bessemer ores for the balance of the season and have endeavored to buy some additional ores for delivery before the opening of navigation, without finding all the ore they desired. The total amount of unsold Bessemer iron to July 1, next, according to probable production of merchant furnaces, is between 50,000 and 75,000 tons, and is probably close to the lower figure. The Steel Corporation is likely to absorb the great bulk of this iron by purchases from month to month. Foundry iron is slightly easier, but the market has held up quite well considering the very small amount of buying, all consumers proposing to hold off until their present contracts have expired, as somewhat lower prices are expected. There has been some buying of small lots for quick shipment. Many consumers have taken iron ahead of contract time, while post-ponements have been rare. Prices average about 25 cents lower than at last report, and are about as follows: F o. b. valley furnace, Bessemer, $17.25 in large lots and $17.50 in lots of less than 5,000 tons; basic, $17.00; No. 2 foundry, $17.00 to $17.25 in small lots and $16.75 in large lots; gray forge, $16.00. Delivered Pittsburg: Bessemer, $18.10 to $18.35; basic, $17.85; No. 2 foundry, $17.60 to $18.10; gray forge, $16.85. F. o. b. Birmingham: No. 2 foundry, $13.75 to $14.00; gray forge, $12.25 to $12.50. Delivered Chicago: Northern No. 2 foundry, $19.00 to $19.25; malleable Bessemer, $19.00 to $19.25; Lake Superior charcoal, $19.75 to $20.00. Delivered Philadelphia: No. 2 X foundry, $18.25 to $18.50; standard gray forge, $16.50 to $16.75. Freight: Valleys to Pittsburg, 85 cents; to Chicago, $2.30. Birmingham to Cincinnati, $3.00; to Chicago, $3.90; to Pittsburg, $4.60; to Philadelphia by all-rail, $4.75; to Philadelphia by rail and water, $4.00.

Ferro-Manganese. — Efforts to break the ferro-manganese market have not been signally successful, and it is now recognized that the scarcity has been due more to increased demand, which is bound to continue, than to decreased consumption. The lowest quotation on large lots for deliveries beginning July 1 is $85 delivered, while small prompt lots continue to bring considerably more than $100.

Steel. — There is very little business being done in billets, shipments still being on old contracts. Small lots for early delivery command $27.00 to $27.50 for Bessemer and $28.00 to $29.00 for open-hearth, f. o. b. Pittsburg. A considerable tonnage of open-hearth has been sold at $29 delivered Philadelphia, but about 50 cents more is now asked. Forging billets have been sold at $32.00 delivered Chicago, but small lots from Chicago mills command a higher price. On March 20 the Carnegie Steel Company announced that its price on sheet bars for second quarter delivery, on contracts which call for a quarterly naming of price, would be $28.00 on long bars and $28.50 on cut bars, an advance of $2.00 per ton. The same week this company changed its mill at Youngstown from sheet bars to rails and apparently is indifferent on the matter of sheet bar sales. It is a question whether sheet bars can be had at a lower price from any other source. The independent sheet and tin plate mills have large tonnages of their products sold for second quarter based on the old price of steel and are not in a very comfortable position.

Plates and Shapes. — A fair amount of new plate tonnage is rolling in, but mills can now make fairly good deliveries, the larger ones in two or three months and the smaller ones in as many weeks. Structural tonnage is fairly large, and mills are sold up full until about the middle of the third quarter, except that some mills rolling only a limited assortment can make earlier deliveries. Prices remain on the basis of 1.60 cents for plates and 1.70 cents for shapes.

Merchant Bars. — The Pittsburg market on iron bars has dropped about $4.00 a ton since last report, being now 1.65 to 1.70 cents, Pittsburg, or 1.60 to 1.65 cents, f. o. b. Youngstown. The Chicago market is a trifle lower, 1.71½ cents, Chicago, being now the open market. At Philadelphia best refined iron bars continue at 1.73½ cents, but bars made partly from scrap are to be had easily at $1.00 to $2.00 per ton less. Steel bars continue at 1.50 cents, Pittsburg.

Sheets and Tin Plates. — New business is very light, while specifications on old contracts which were made before the last advance, and chiefly before the last two advances, are very heavy, the mills being thus sold up until nearly the end of the second quarter. On such small business as comes up the regular

market prices are well maintained, at $3.50 for 100-pound coke tin plates, 2.40 cents for black sheets, No. 28 gauge, and 3.45 cents for galvanized sheets. A 5-cent rebate is generally given on any desirable order. The advance of $2.00 a ton on sheet bars on quarterly contracts has given considerable concern, and if consumers have to pay this advance it will probably result in the prices just quoted being done when the large business comes up again. Otherwise it was expected that prices would sag off.

Scrap. — The scrap market went off further early in March, but about the middle of the month heavy melting scrap became firmer, although not quotably higher, other grades continuing to decline. In the third week of the month the three principal buyers in the Pittsburg district took 3,000 tons or more each of heavy melting scrap at $15.00, delivered. Prices are now about as follows, delivered Pittsburg district: Heavy melting scrap, $15.00 to $15.25; old rails, long lengths, $15.50 to $16.00; cast borings, $8.25 to $8.50; wrought turnings, $11.75 to $12.00; sheet scrap, $13.50 to $14.00.

Connellsville Coke. — The coke market is firmer, prompt lots of standard Connellsville being $2.30 to $2.40 for furnace and $3.00 to $3.10 for 72-hour foundry.

STATISTICS

Production of Pig Iron in Canada in 1905.* The American Iron and Steel Association has received direct from the manufacturers the statistics of the production of all kinds of pig iron in Canada in the calendar year 1905. Full and complete reports have been received from every pig-iron maker in the Dominion.

The total production of all kinds of pig iron in Canada in 1905 amounted to 468,003 gross tons, against 270,942 tons in 1904, an increase of 197,061 tons, or over 72 per cent. The production in 1905 was much the largest in the history of the Dominion and exceeded that of 1902, the year of next largest production, by 148,446 tons, or over 46 per cent.

In the first half of 1905 the pig-iron production of Canada amounted to 210,206 tons and in the second half to 257,797 tons, an increase of 47,591 tons. Of the total production in 1905, 432,870 tons were made with coke, 4,836 tons with charcoal and coke mixed, and 30,297 tons with charcoal.

The production of basic pig iron in Canada in 1905 amounted to 172,102 tons, against 70,133 tons in 1904, and the production of Bessemer pig iron to 149,203 tons, against 26,016 tons in 1904. Basic pig iron was made in 1905 by three companies owning six furnaces, and Bessemer pig iron by two companies owning three furnaces. The basic pig iron was all made with coke for fuel, but the Bessemer pig iron was made with coke alone, charcoal alone and charcoal and coke mixed. Canada has not made spiegeleisen or ferro-manganese since 1899, when small quantities of both metals were produced at Bridgeville, Nova Scotia, by a furnace which has since been abandoned.

The production of malleable Bessemer pig iron in Canada in 1905 amounted to 3,300 tons; foundry pig iron, 139,528 tons; forge pig iron, 3,500 tons; and white and mottled and miscellaneous grades of pig iron, including castings made direct from the furnace, 370 tons. Neither ferro-silicon nor ferro-phosphorus was made. The quantity of limestone consumed for fluxing

* " The Bulletin, American Iron and Steel Association," February 15, 1906.

purposes by blast furnaces in Canada in 1905 amounted to 290,310 tons.

The following table gives the total production of all kinds of pig iron (including spiegeleisen and ferro-manganese) in Canada from 1894 to 1905. Prior to 1894 the pig-iron production of Canada was not ascertained by this association.

Years	Gross Tons	Years	Gross Tons	Years	Gross Tons
1894	44,791	1898	68,755	1902	319,557
1895	37,829	1899	94,077	1903	265,418
1896	60,030	1900	86,090	1904	270,942
1897	53,796	1901	244,976	1905	468,003

On December 31, 1905, Canada had 14 completed blast furnaces, of which 9 were in blast and 5 were idle. Of the total, 10 usually use coke for fuel and 4 use charcoal. In addition, one furnace, to use coke, was being built and 3 coke furnaces were partly erected on December 31. Work on the partly erected furnaces was, however, suspended some time ago.

During the first half of 1905 Canada had 13 of its completed furnaces in blast, and during the last half it had 12 furnaces in blast. In the first half of 1904 it had 10 furnaces in blast, and during the last half of the year 10 furnaces were also running.

RECENT PUBLICATIONS

Traité théorique et pratique de Métallurgie Générale, by L. Babu, chief engineer of mines, professor at the Ecole Nationale des Mines. Volume II. 705 7 × 9½-in. pages; illustrated. Librarie Polytechnique. Ch. Béranger. Paris and Liége. 1906. Price, 25 francs. — This second volume of Professor Babu's important metallurgical work is devoted chiefly to the study of fuels, refractory materials, metallurgical furnaces and appliances. The exhaustiveness, method and clearness of the treatment should appeal strongly to students of metallurgy to whom the book can be warmly recommended.

The Journal of the Iron and Steel Institute, Vol. LXVIII (No. 2, 1905). Edited by Bennett H. Brough, secretary. 879 5½ × 8½-in. pages; illustrated. E. and F. N. Spon, Limited. London. 1906. Price, 16s. — The present volume of the " Journal of the Iron and Steel Institute," which is the sixty-eighth of the series, contains the minutes of the proceedings of the autumn meeting held in Sheffield, September 26 and 27, 1905. It includes the usual valuable notes on the progress of the home and foreign industries and the following papers read and discussed at the meeting: " The Department of Iron and Steel Metallurgy at the University of Sheffield," by J. O. Arnold; " The Thermal Transformations of Carbon Steels," by J. O. Arnold and A. McWilliam; " Overheated Steel," by A. W. Richards and J. E. Stead; " The Use of Vanadium in Metallurgy," by L. Guillet; " Steel Use for Motor-Car Construction in France," by L. Guillet; " Segregation in Steel Ingots," by B. Talbot; " A Manipulator for Steel Bars," by D. Upton; " Reversible and Irreversible Transformations of Nickel Steel, " by L. Dumas; " The Presence of Greenish-Colored Markings in the Fractured Surfaces of Test Pieces," by Capt. H. G. Howarth; " Wear of Steel Rails on Bridges," by T. Andrews; " On Troostite," by Dr. C. Benedicks; " Note on the Occurrence of Copper, Cobalt and Nickel in American Pig Irons," by E. D.

Campbell; "The Influence of Nickel and Carbon on Iron," by G. B. Waterhouse; "Researches on the Magnetic and Electric Properties of Various Kinds of Sheet Steel and Steel Castings," by Gunnar Dillner and A. F. Enström.

Traité de Chimie Appliquée, by C. Chabrié, in charge of the Course in Applied Chemistry at the Faculty of Sciences of the University of Paris. Vol. I. 876 6 × 9½-in. pages; 271 illustrations. Mason et Compagnie. Paris. 1905. Price, 22 francs. — This work will be complete in two volumes containing about 1,700 pages. The first volume which we have before us deals with the apparatus used for the manufacture of chemical products, the purification of water, the products of the large mineral industries, metallurgical products and special products from the electric furnaces, limes, mortars and cements, fuels, products of the saponification of fatty substances, etc. The author treats this complex subject in a clear and comprehensive manner which should strongly appeal not only to students but also to industrial chemists. The book is well printed and illustrated and substantially bound.

Manuel d'Analyse Chimique, by Eug. Prost, D.S., University of Liége. 443 5 × 8½-in. pages; illustrated. Librarie Polytechnique. Ch. Béranger. Paris and Liége. 1903. Price, 12.50 francs. — This book contains descriptions of analytical methods for the analysis of fuels, water, minerals, metals, alloys and other metallurgical products. The author's aim was not to describe all the analytical methods used, but rather only those selected ones which are most likely to yield satisfactory results. The book is attractively printed and bound.

The Encyclopedia of Practical Engineering and Allied Trades, edited by Joseph G. Horner. Vols. I and II. Each volume 240 7 × 10-in. pages; profusely illustrated. Virtue & Co. London. Price, each volume, 7s. 6d. — This encyclopedia, of which the first two volumes have recently been published, will be completed in ten volumes to appear at intervals of three months. The work is intended to cover the entire practice of civil and mechanical engineering. The following extracts from the author's preface will indicate the scope and aim of this encyclopedia:

"This intensity of specialization produces narrow views and narrow ideals, and tends to induce only a languid interest in the related work that lies beyond. It renders the acquisition of minute knowledge in the other fields very difficult. Especially on those of limited means do these conditions press hardly. The mass of technical literature is too great to be purchased or even assimilated, neither is it essential except to a few. The requirements of most people are met by a special knowledge in one branch, and a general acquaintance with others related thereto. Hence the popularity enjoyed by encyclopedias of a literary and scientific cast. It is believed that there is scope for such a work for the engineering and allied trades. Almost every one makes or uses machinery now, and to all such, whether employers or workpeople, these volumes will appeal. It is hoped that nothing which is of interest to those engaged in any of the engineering industries will be omitted from its pages. All the different subdivisions have been well considered in the selection of subject matter, and in the due balance of articles, according to their relative importance."

A special feature of this work is its "shoppy" character. It is written for the men in the shops more than for any other class. For this reason, too, it is of especial value to students, who, whatever they may learn of theory in technical schools, certainly do not learn shop work as it is performed under factory conditions.

Year Book of the Scientific and Learned Societies of Great Britain and Ireland. Twenty-second annual issue. 309 5½ × 8½-in. pages. Charles Griffin & Co. London. 1905. Price, 7*s*. 6*d*. — This year book, of which the present volume is the twenty-second annual issue, contains short descriptions of the work done in science, literature and art during the year 1904–05, the information being obtained from official sources. The subjects are classified as follows: Science Generally, Astronomy, Mathematics and Physics, Chemistry and Photography, Geography, Geology and Mineralogy, Biology, including Microscopy and Anthropology, Economic Science and Statistics, Mechanical Science and Architecture, Naval and Military Science, Agriculture and Horticulture, Law, Literature and History, Psychology, Archæology, Medicine, Miscellaneous. The various papers published during the year are classified under the name of the

Society before which they were read. The names of officers, dates of meetings, membership and publications are also given for each society.

Doble Tangential Water Wheels. An illustrated pamphlet issued by the Abner Doble Company. San Francisco, U. S. A. — This is an unusually attractive pamphlet describing, with excellent illustrations, the Doble Tangential water wheels. It also contains some useful water wheel tables, — pipe and reference tables, conversion factors and useful hydraulic information.

BOOKS RECEIVED

The following books have been received and will be reviewed in an early issue of the *Iron and Steel Magazine.*

The Mineral Industry. Volume XIII. 589 6 × 9-in. pages; illustrated. The Engineering and Mining Journal. New York and London. 1905. Price, $5.00.

American Men of Science, edited by J. McKeen Cattell. 364 7½ × 10-in. pages. The Science Press. New York. 1906. Price, $4.00.

The North of England Institute of Mining and Mechanical Engineers. Report of the Committee upon Mechanical Coal Cutting. 109 6 x 9½-in. pages; illustrated; paper covers. Published by the Institute. New Castle-upon-Tyne. 1905. Price, 10s.

Modern Machine Shop Construction, Equipment and Management, by Oscar E. Perrigo. 343 7 x 10-in. pages; illustrated. The Norman W. Henley Publishing Company. New York. 1906. Price, $5.00.

Das Neue Institut für Metallhuttenwesen und Elektrometallurgie an der Koniglichen Technischen zu Aachen, by Dr. Wilhelm Borchers. 61 8½ x 12-in. pages; illustrated; paper covers. Wilhelm Knapp. Hall a. s. 1903. Price, 6 marks.

A Pocket Book of Mechanical Engineering, by Charles M. Sames. 168 4 × 7-in. pages; illustrated; flexible covers. Charles M. Sames. Jersey City. 1905. Price, $1.50.

A Treatise on Producer Gas and Gas Producers, by Samuel S. Wyer. 296 6 × 9-in. pages; illustrated. The Engineering and Mining Journal. New York and London. 1906. Price, $4.00.

Eisenhuttenkunde, dritter band, Die Gewinnung des Eisens aus den Erzen, dritte Lieferrung (Schluss des III Bandes), by Dr. Hermann Wedding. 300 6 × 9-in. pages; numerous plates and other illustrations. Friedrich Vieweg und Sohn. Braunschweig. 1906.

Poor's Directory of Railway Officials, A Supplement to Poor's Manual of Railroads. 244 6 × 9-in. pages; paper covers. Poor's Railroad Manual Company. New York. 1906.

Traité Pratique de la Fonderie du Fer, by G. Van Der Haeghen and L. Ledent. 784 5 × 8-in. pages; illustrated; paper covers. Charles Desoer. Liége, Belgium. 1905.

La Fonderie Moderne, Bibliothèque du Mois Scientifique et Industriel. 686 6 × 9½-in. pages; illustrated. Vve. Ch. Dunod. Paris. Price, 2.50 francs.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

810,228. Furnace Roof. — Edwin E. Slick, Pittsburg, Pa. Filed July 1, 1904.

810,286. Furnace-Charging Apparatus. — William G. Kranz, Sharon, Pa., assignor to the National Malleable Castings Company, Cleveland, Ohio, a corporation of Ohio. Filed June 30, 1905.

810,654. Ingot-Casting Machine. — John Illingworth, Newark, N. J. Filed June 17, 1905.

810,864. Apparatus for Chilling Cinder or Slag. — Frank K. Hoover and Arthur J. Mason, Chicago, Ill. Filed August 31, 1903.

810,865. Method of Chilling Cinder or Slag. — Frank K. Hoover and Arthur J. Mason, Chicago, Ill. Filed August 31, 1903.

810,904. Apparatus for Grinding or Crushing Foundry-Sand, etc. — Philibert Bonvilain. Paris, France. Filed June 1, 1904.

811,006. Converter. — George T. Walker, Washington, D. C. Filed January 10, 1905.

811,097. Apparatus for Treating Molten Metal. — Joseph S. Seaman, Pittsburg, Pa. Filed May 23, 1904.

811,143. Compressing Steel in Conical Molds. — Henri Harmet, St. Etienne, France. Filed October 7, 1902.

811,208. Gas-Producer. — Carleton Ellis, New York, N. Y., assignor to Combustion Utilities Company, New York, N. Y., a corporation of New York. Filed March 15, 1905.

811,522. Treating Molten Metal. — Joseph S. Seaman, Pittsburg, Pa. Original application filed May 23, 1904.

812,170. Apparatus for Magnetic Separation of Iron Ore. — Gustaf Grondal, Djursholm, Sweden. Filed November 12, 1903.

812,171. Magnetic Ore-Separator. — Gustaf Grondal, Djursholm, Sweden. Filed November 3, 1904.

812,172. Magnetic Separation of Iron Ore. — Gustaf Grondal, Djursholm, Sweden. Original application filed November 12, 1903.

812,173. Magnetic Ore-Separator. — Gustaf Grondal, Djursholm, Sweden. Original application filed November 3, 1904.

812,174. Method of Manufacturing Iron Sponge. — Gustaf Grondal. Djursholm, Sweden. Original application filed March 31, 1903.

812,178. Melt or Bath for Hardening Steel. — Shipley N. Brayshaw, Hulme, Manchester, England, assignor to George Nash, New York, N. Y. Filed March 31, 1905.

812,228. Fluid-Pressure Metal-Working Machine. — Casimir

von Philp, Bethlehem, Pa., assignor to The Bethlehem Steel Company, South Bethlehem, Pa., a corporation of Pennsylvania. Filed August 24, 1904.

812,247. PROCESS OF REDUCING IRON ORE. — Gustaf M. Westman, New York, N. Y. Filed June 24, 1903.

812,619. METHOD OF PRESERVING THE INNER WALLS OF FURNACES. — Friedrich C. W. Timm, Hamburg, Germany. Filed April 21, 1905.

812,810. CAST MANGANESE-STEEL RAIL. — Walter Brinton, Highbridge, N. J., assignor to Taylor Iron and Steel Company, a corporation of New Jersey. Filed May 4, 1904.

812,811. PROCESS OF TREATING MANGANESE STEEL. — Walter Brinton, Highbridge, N. J., assignor to Taylor Iron and Steel Company, a corporation of New Jersey. Filed May 5, 1904.

813,022. CHARGING-MACHINE. — Augustin L. J. Queneau, South Bethlehem, Pa. Filed January 16, 1905.

813,278. PROCESS OF COMBINING TITANIUM WITH OTHER METALS. — Ferdinand E. Canda, New York, N. Y., assignor to Chrome Steel Works, Chrome, N. J., a corporation of New Jersey. Filed January 28, 1905.

813,442. GAS-RELIEF VALVE FOR BLAST-FURNACES. — Eugene L. Messler, Pittsburg, Pa.

813,483. ANNEALING OR MALLEABLIZING OVEN. — William L. Casaday and August Bergman, South Bend, Ind.

GREAT BRITAIN

12,652 of 1905. STEEL PROCESS. — H. H. Campbell, Steelton, Pa. Removing excess of chromium from steel intended for structural purposes by continuing the bessemerizing after the carbon and silicon have been removed, and removing the slag containing the oxidized chromium before starting recarburizing.

5,975 of 1905. HOT BLAST STOVE. — J. Evans and D. Lewis, Dowlais, Wales. Improved construction of hot blast stoves with the object of making them more easily cleaned, and so preventing the corrosion of the floor plates.

16,232 of 1905. BRIQUETTING IRON ORE. — U. Wedge, Ardmore, Pennsylvania. For agglomerating fine iron ores, mixing with clay and heating to the melting point of iron oxide.

16,233 of 1905. BRIQUETTING IRON ORE. — U. Wedge, Ardmore, Pennsylvania. For agglomerating fine iron ores, mixing with Portland cement and heating to the melting point of the Portland cement.

16,234 of 1905. BRIQUETTING IRON ORE. — U. Wedge, Ardmore, Pennsylvania. For agglomerating fine iron ores; mixing with sulphate of iron and heating to a temperature at which the sulphur is driven off.

5,465 of 1905. BLAST FURNACE CHARGING APPARATUS. — A. Sahlin, London. An improved blast furnace charging apparatus consisting of an upper receiving hopper, a distributing spout and a lower revolvable hopper.
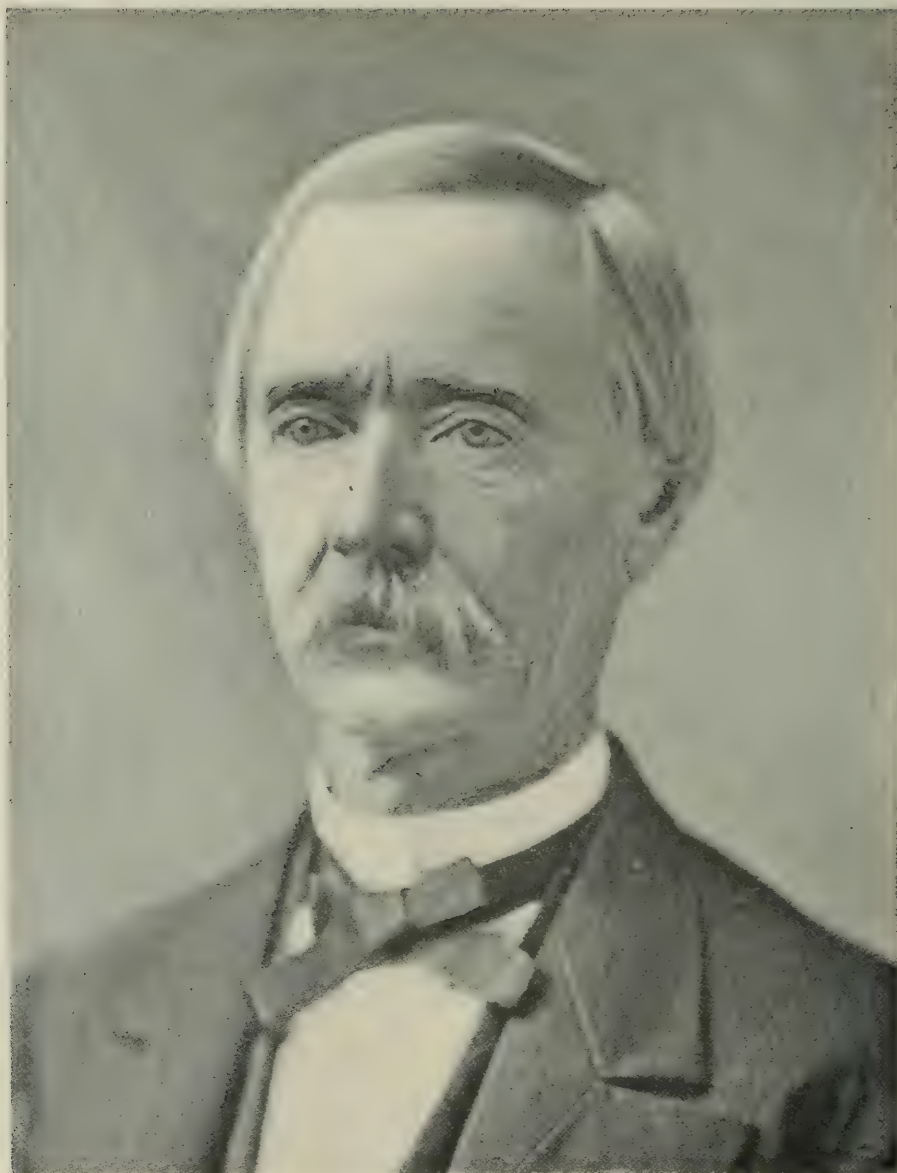
WILLIAM KELLY

THE EQUILIBRIUM CURVES OF THE SYSTEM IRON AND CARBON *

By PROF. H. v. JÜPTNER

Special Contributor to The Iron and Steel Magazine

THE numerous experiments which have been made on the equilibrium of iron-carbon alloys makes desirable a comparative revision of results such as is attempted in the following pages. The investigations of this subject are made more difficult because on one hand the chemical separation and examination of the components have succeeded at best only partially, while on the other hand we are dealing with very complicated systems in which not only stable but also unstable equilibrium can occur; and even in the slow course of the processes in case of solid bodies, phenomena of over-cooling frequently occur and an equilibrium is seldom reached. We will discuss the separate equilibrium curves in order.

I. The equilibrium in iron-carbon alloys in solid and fluid condition.

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* Received March 15, 1906.

The melting point of pure iron has only recently been determined at 1540° C. by Gürller and Taurmann.* In the following we will assume the melting point to be 1550° C.

The following observations are the basis of our considerations:

a. Observations of the point of solidification (beginning of solidification) according to Mannesmann and Osmond, calculated by the author:†

Per Cent Carbon	Mannesmann	Osmond
o	1550°C.	1550°C.
0.5	1470	....
1.0	1400	....
1.3	1360	1410
1.8	1310	1320
2.7	1250	1260
3.5	1200	1200
4.3	1160	1125
5.5	....	1260

b. Temperatures of the beginning and end of solidification according to Roberts-Austen: ‡

Per Cent Carbon	Beginning of Solidification	End of Solidification
1.37	1415°C.	——
1.62	1395	——
1.78	1360	1100
1.92	1330	1100
2.68	1265	1130
3.08	1220	1112
3.44	1194	1117
4.30	1120	1120
4.50	1160	1120
5.50	1270	1120

c. Point of solidification according to Carpenter and Kelling.§ The calculations were made on the assumption that

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* Zeit. für angewandte Chemie, 1905.

† Siderologie, 2d vol.

‡ From the diagram in the Fourth Report of the Alloys Research Committee.

§ " Journal of the Iron and Steel Institute," 1904, I.

the temperature 1136° C. was correctly determined, while all others had errors proportional to the temperature.

Per Cent Carbon	Beginning of Solidification (directly observed)	End	Beginning of Solidification (calculated)	End
0	1505	1505	1550	1550
0.02	1504	1470	1536.7	1500.7
0.12	1504	1470	1536.7	1500.7
0.16	1498	1465	1542.4	1505.1
0.17	1497	1450	1541	1488.3
0.24	1492	1448	1535.4	1486.1
0.38	1479	1416	1520.8	1451.1
0.47	1482	....	1524.8	......
0.53	1473	1404	1492.1	1436.7
0.61	1469	1394	1509.6	1424.9
0.80	1457	1351	1492.8	1379.4
0.80	1454	....	1496.2	......
0.81	1460	1351	1499.5	1379.4
0.93	1443	....	1480.5	......
1.31	1426	1286	1461.4	1304.3
1.51	1406	1244	1437.9	1257.5
1.69	1388	....	1418.7	......
1.81	1383	....	1413.2	......
1.85	1383	1179	1413.1	1184.2
1.97	1367	....	1395.2	......
2.12	1350	1110	1376.1	1106.8
2.21	1354	1107	1380.6	1103.5
2.25	1352	1122	1378.4	1120.7
2.25	1348	1122	1361.7	1120.7
2.47	1330	1134	1353.7	1133.7
2.63	1305	....	1325.6	......
2.67	1306	....	1326.7	......
2.74	1300	1139	1320	1139.4
2.85	1292	1139	1311	1139.4
3.03	1277	1139	1294.2	1139.4
3.29	....	1141	......	1141.3
3.42	1238	1114	1250.4	1111.3
3.51	1230	1136	1241.5	1129.3
3.87	1190	1144	1196.6	1145
3.98	1171	1138	1175.3	1138.2
4.37	1136	1136	1136	1136
4.50	1146	1146	1147.2	1147.2

d. Point of solidification according to F. Wust.* (The beginning of solidification was not accurately observed and no separation of dross [kish?] noted.)

* " Metallurgie," 1906, p. 1.

Per Cent Carbon	Beginning of Solidification	End	Graphite Per Cent*	Combined Carbon Per Cent*
2.94	. . . .	1132°C	0.04	2.90
3.02	1220 (?)†	1135	0.37	2.65
3.29	. . . .	1112	0.05	3.24
3.76	1160 (?) 1170 (?)	1138	2.33	1.43
3.79	. . . .	1141	2.24	1.55
3.94	. . . .	1149	2.28	1.66
4.04	. . . .	1122	1.75	2.29
4.66	. . . .	1130	3.22	1.44
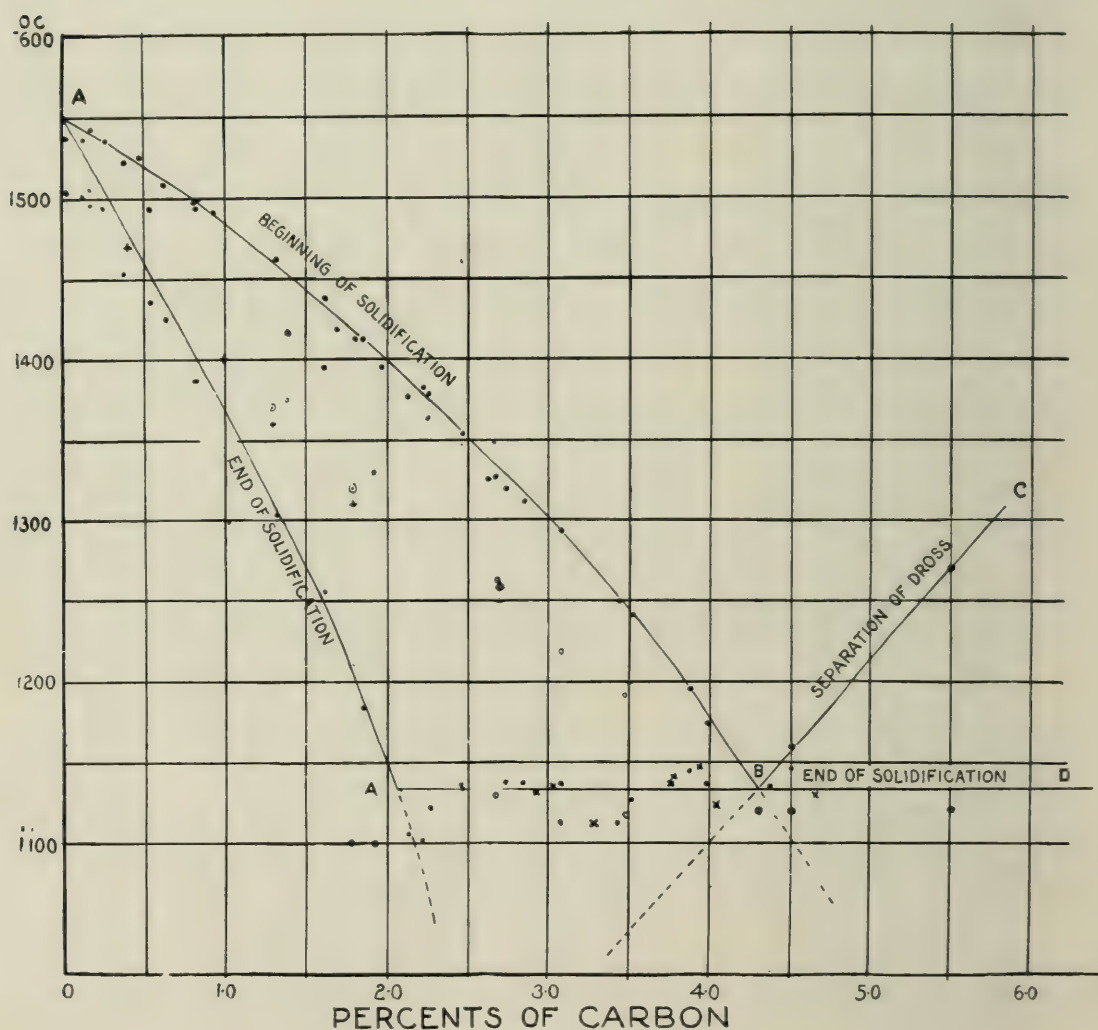
All these points of which those under **c** and **d** are to be considered the most trustworthy are plotted in the diagram, Fig. 1, and the probable equilibrium curves are drawn. AB

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* These data afford a conclusion concerning possible over-cooling.

† Taken from the cooling curve.

corresponds to the beginning, AA the end of solidification, BC to the separation of graphite from cast iron saturated with carbon, and ABD to the solidification of the eutectic alloy.

As one sees, under-coolings take place, especially in the older observations and with very low percentages of carbon.

The end A of the eutectic line lies at 2.07 per cent carbon, almost exactly where Roozeboom presupposed it. The eutectic point B lies at about 4.3 per cent carbon.

These curves could be used to calculate the molecular size of the carbon dissolved in iron. For this the equation of Róthmund,*

$$\triangle t = E \frac{C_1 - C_2}{m}$$

must be used, in which $\triangle t$ represents the melting point, E the so-called molecular melting point, C_1 and C_2 the per cent of carbon in the iron and in the separated mixed crystals. E is obtained from $$E = \frac{0.02 T^2}{W},$$ where T represents the melting point of iron in absolute temperature and W the melting heat in calories per unit of weight. Consequently we have

$$m = \frac{C_1 - C_2}{\triangle t} \cdot \frac{0.02\ T^2}{W} = \frac{48050(C_1 - C_2)}{\triangle t. W}$$

The accuracy of the calculation is lessened by the fact that the latent heat of pieces of iron is not sufficiently known. The author has at one time† assumed with Campbell that it was 20 calories, while it may, according to the formula of Person,

$$W = 0.00167 K \left(1 + \frac{2}{\sqrt{d}} \right),‡$$

be reckoned as 57 calories. But since the latent heat of fusion of nickel (so similar to iron) is only 4.64 calories, while according to the formula of Person it is calculated at 29.91 calories, all these values are very doubtful. Nevertheless we are able by the help of our diagram to calculate the expression

$$\frac{48050\ C_1 - C_2}{\triangle t}$$

for a number of points. We obtain thus:

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* Zeit. für physikalische Chemie, 24, p. 705.
† Siderologie, I, p. 190.
‡ K = elasticity and *d* specific weight.

C_1 Per Cent	C_2 Per Cent	$C_1 - C_2$ Per Cent	$\triangle t$	$\dfrac{48050\,(C_1 - C_2)}{\triangle t}$
0.15	0.04	0.11	10	528.55
0.50	0.17	0.33	30	528.55
0.80	0.28	0.52	50	499.72
1.3	0.5	0.8	90	464.65
2.3	1.0	1.3	180	336.35
3.00	1.35	1.65	250	317.13
4.0	1.9	2.1	370	273.89
4.30	2.07	2.23	414	259.47

If we choose now for the latent heat of fusion on the one hand 20 calories and on the other the 57 calories reckoned from the formula of Person, we obtain the following molecular weights (m) and number of atoms (n) per molecule of dissolved carbon.

Point of Solidification in Deg. C.	Molecular Weight of C (m)		Number of Atoms in Carbon Molecules (n)	
	$W = 20$	$W = 57$	$W = 20$	$W = 57$
1540	26.43	9.27	2.20	0.77
1520	26.43	9.27	2.20	0.77
1500	24.98	8.77	2.08	0.73
1460	23.23	8.15	1.77	0.68
1370	16.82	5.90	1.40	0.49
1300	15.85	5.56	1.32	0.46
1180	13.69	4.80	1.14	0.40
1086	12.97	4.55	1.08	0.38

Since parts of atoms are impossible, the latent heats of fusion according to the formula of Person are proved untenable. If $W = 20$ were correct, the carbon in fluid iron would be dissolved as a molecule of 2 atoms, since only the most dilute solutions lead to accurate results, while with increasing concentration the variation from the Rothmund formula increases. If, on the other hand, the carbon in fluid iron is dissolved as a molecule of 1 atom, the latent melting heat of iron must amount to about 40 calories.

AN ETCHING METHOD FOR DETERMINING WHETHER STEEL HAS BEEN MADE BY THE CRUCIBLE PROCESS *

By JAMES A. AUPPERLE, Indianapolis, Ind.

Laboratory of E. C. Atkins & Co.

IT has been the impression of many chemists that the silicon and oxygen determinations would indicate the difference between steel made by the crucible and other processes.

While ordinarily the silicon is under 0.02 per cent in open-hearth sheet steel, silicon can be added, and is added for steel castings which will run as high as 0.40 per cent silicon.
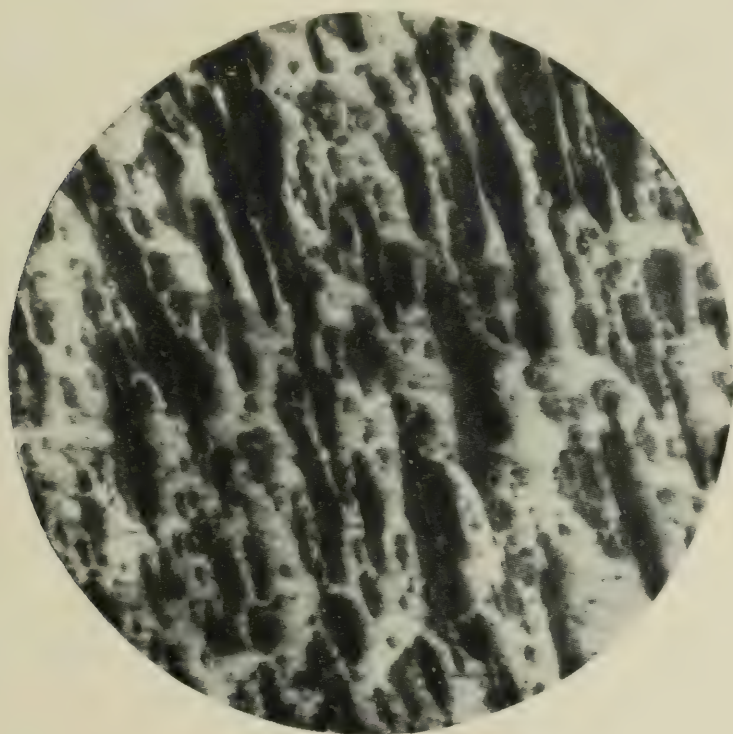
Fig. 1

The matter of oxygen in steel was carefully investigated at the research laboratory of the Illinois Steel Company, at South Chicago, and it was found that Bessemer steel that contained 0.12 per cent oxygen before the addition of ferro-manganese, after adding the ferro-manganese the oxygen in the finished steel was under 0.03.

The oxygen was determined by an elaborate method that involved the use of three furnaces, and 15 grams of steel were used in determination.

The finished steel would average less than 0.03 per cent oxygen, and I believe these are maximum figures. While crucible steel contains but a trace of oxgyen, the method for the determination is too tedious for daily use in a steel works laboratory, and the maximum amount in crucible and the minimum amount in Bessemer or open-hearth steel interlace, so that a declaration as to whether the steel is of crucible origin becomes problematical when the determinations of the elements fail of positive identification.

Fig. 1 shows the structure of a deeply etched sample of open-hearth steel of the following analysis:

Carbon	1.09
Manganese	.20
Silicon	.10
Sulphur	.02
Phosphorus	.01

Fig. 2 has had the same treatment as Fig. 1 and is crucible steel of the following analysis:

Carbon	1.000
Manganese	.300
Silicon	.165
Sulphur	.020
Phosphorus	.016

From a chemical standpoint the difference between the two is not material, and I doubt whether the tensile strength would vary sufficiently to indicate that they were made by different processes.

The method I use is as follows:

Specimens of steel are secured of about $1\frac{1}{2}$ inches square.

As many as are to be tested are placed in a large beaker, along with a standard known to be crucible steel. For each specimen 100 cubic centimeters of dilute sulphuric acid is used (90 cubic centimeters water and 10 cubic centimeters 1.84 acid) together with 3 grains of permanganate of potash for each specimen.

Thus, if ten specimens are to be etched, use 1 liter of dilute acid and 30 grams of permanganate crystals.

Samples remain at room temperature over night and in the morning, if solution is colored red or brown from manganese compounds, boil until decolorized, adding more acid if necessary. When solution is free from red or brown colors the samples are washed in water and wiped to remove carbonaceous matter.

They can then be examined by the unaided eye. The open-hearth and Bessemer steel will be etched in grooves, in the
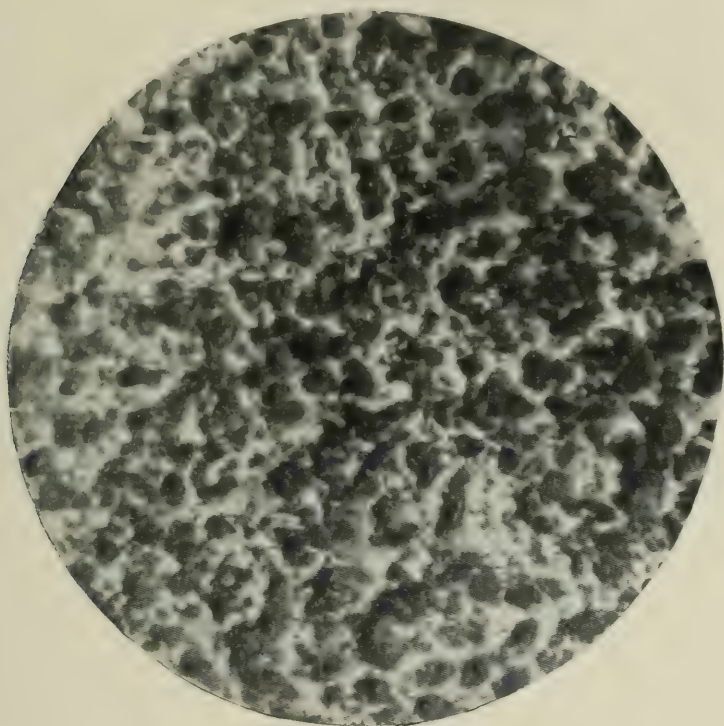
Fig. 2

direction of rolling; the cross section at the edge will be honey-combed and feel rough to the touch.

The crucible steel will not be etched in grooves, but will show a close structure with perhaps an appearance of having minute pittings.

All edges of the crucible steel will be comparatively smooth.

These structures being dead black, it is necessary (when examining them microscopically) to polish on a felt disk that has been dressed in 10 M. P. carborundum or rouge.

OPEN-HEARTH STEEL CASTINGS.* — IV

By W. M. CARR

(Continued from page 301)

MANIPULATION OF HEATS IN ACID PRACTICE

GIVEN an acid-lined hearth and stock for melting purposes, " the next step will be to consider some of the changes that take place in the conversion of the materials charged, into steel. As has been mentioned, the only elements that are confined within stated limits are the sulphur and phosphorus. Considerable latitude remains in making up the charge in regard to the available silicon, carbon and manganese carried in by stock. Assuming the stock to be made up of pig iron, billets, blooms, plate clippings, axle-butts, defective steel castings, shop scrap, or wasters in varying proportions, a charge of 24,000 pounds will be studied because the diagram herewith shown was plotted on a heat of that size.

The proportions and changes would be relatively the same in a 20-ton heat. The charge will be as follows:

Acid pig iron =	3,600	15 per cent
Mixed scrap =	20,400	85 ,, ,,
Lbs.	24,000	100 per cent

AVERAGE COMPOSITION

C	.90	per cent
Mn	.47	,, ,,
Si	.40	,, ,,
S	.024	,, ,,
P	.028	,, ,,

The order of charging will be as follows: First, two thirds of pig iron; second, lightest sections of scrap; third, heaviest sections of scrap; fourth, one third or remainder of pig iron.

The object in charging the pig iron in two portions, with the larger on the bottom, is to protect it from scorification caused by the oxide of iron always formed in the melting of the scrap, which oxidizes at a faster rate than the pig iron. The

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* " The Iron Trade Review," April 12, 1906.

portion of pig iron on top is the first to melt and in dripping over the scrap lowers the melting point of the latter and in a measure protects it from undue burning or oxidization until the whole mass sinks below the slag formed during the exposure of stock to the flame action.

The length of time occupied in charging varies as to the size of the pieces of scrap charged and the room it offers to follow with the rest of the stock.

Occasionally there may be some little time elapse before the bulky stock may have partly melted and subsided before the charge can be completed. Usually the length of time consumed in charging is about one to one and one-half hours.

The charging of stock being completed, the history of the heat is divided into two stages: first the melting; second, the complete fusion and conversion of the materials. During the first period little or no change takes place in the composition, the main function being the transmission of the solid stock to the liquid form and with it the formation of the slag which is to play an important part in the subsequent conversion of the stock to steel.

The length of time in liquefying the stock is normally from two to two and one-half hours, and during that time the temperature of the furnace is gradually increasing, owing to the method of regeneration already explained.

It is certain that some changes occur as soon as the stock begins to melt and the slag begins to form. Perhaps the most pronounced change takes place by flame action on the exposed stock, it being strongly oxidizing; but not until the charge becomes entirely fused or liquid does the active part of conversion begin.

With complete liquation of charge, the flame simply becomes a vehicle of heat, and under the practiced eye of the melter the thermal conditions are so maintained that the temperature of the bath is gradually increased as the conversion progresses. It is necessary that the temperature of the bath be gradually increased because of the influence of carbon. In general terms, the fusing point of iron or steel depends upon the amount of that element, the higher percentage fusing at a lower point thermometrically than the lower amounts.

Glancing at the diagram, the carbon will be seen as gradually increasing as the conversion progresses.

Without a corresponding increase in temperature, the bath of metal would become pasty, and with the bath in that condition there would be losses.

In order to induce liquation at the first stage of conversion it is necessary to introduce carbon to that being furnished by the pig iron of the charge. Fluidity and proper thermal conditions succeeding are then easily attained.

Assuming the stock to be melted and having passed from *direct* flame action below a covering of slag the functions of that will next be considered. The existence of the slag is derived from sand carried in mechanically by the stock, the oxidization of the silicon contained in the pig iron and scrap to silica, the oxidization of the manganese brought in by them to manganous oxide, some scorification of hearth and the oxidization of iron to ferrous oxide.

Normally the slag is automatically formed, in regard to composition, throughout the progress of the heat.

Should there be an excess of FeO due to low silicon pig iron, there would be an excessive cutting of hearth, and it might be necessary to add sand to furnish the needed SiO_2 to form the adjustment of proper slag composition.

Approximately, a normal slag in an acid heat consists of nearly equal parts SiO_2 acid and $FeO + MnO$ (bases), and this composition will exist throughout the heat with a gradual increase in volume resulting from the continued oxidization of silicon and manganese and by the additions of iron ore.

The oxidization of the carbon causes a lively bubbling in the bath by the liberation of CO as a result of the exchange between the FeO of the slag and the oxygen furnished by iron-ore additions, which may be expressed as follows:

$$C + O = CO \text{ or } C + FeO = Fe + CO.$$
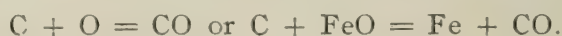
The metallic iron reduced from the slag's FeO and that brought in by the iron ore (Fe_2O_3) is immediately absorbed by the bath. Were there no additions of ore, the slag would become thick and pasty owing to the decrease in the base FeO.

Test samples are taken regularly after melting, the fractures of which indicate the amount of carbon in them giving guidance to the melter as to the necessary additions of ore.

Diagram Showing Variations in Composition of a Normal Acid Open Hearth heat

Metals Melting

Metals Melted

Commenced Finished
Charging Charging
A.M. P.M.

Heat
Tapped

11   12.69   4.02   4.17   4.32   4.47   5.02   5.17   5.32   5.52

Initial Carbon

.90

.80

.70   Mn .71

.60

.50
.47   Initial Manganese

.40   Initial Silicon

.30   Si. .31

.20   C. .22

.10

.090

.080

.070

.060

.050

.040   S. .038

.030   P. .029
.028
Initial Phosphorus
.024
Initial Sulphur
.020

.010

No information as to any reactions during this period

60 # Ore Added

60 # Ore Added

60 # Ore Added

28 # Added

244 # Added

79 # Added

Final Analysis

Initial Phosphorus

Initial Sulphur

In acid practice, only the carbon is considered in preliminary tests, but for detailed information they may be examined for the usual elements. When in the judgment of the melter the bath needs no more iron ore and the decreasing carbon has reached a predetermined point (which can be accurately estimated by the practiced eye) preparations are then made to finish the heat.

The thermal conditions being satisfactory, and the slag normal, deoxidizers and recarburizers in the shape of ferrosilicon and ferro-manganese are then added and the heat of finished steel is ready to tap or draw off into a hot ladle.

Details of Recarbonizing

Assuming that the chemical composition of the metal going into castings shall be as follows:

C	.25 per cent
Si	.300 ,, ,,
S	.040 ,, ,, or less
P	.040 ,, ,, ,, ,,
Mn	.75 ,, ,, ,, ,,

which may be considered as representative of regular practice on medium hard cast steel. Taking as a basis 24,000 pounds of metal charged, the weights of ferro-silicon and ferro-manganese, 792 and 305 pounds respectively, from them there will be furnished silicon, manganese and carbon plus those several elements contained in the bath at the time of final additions. According to these analyses the available elements will be, first, silicon from the FeSi with 10 per cent Si,

$$792 \times .10 = 79.2 \text{ lbs. Si};$$

second, manganese from the FeMn with 80 per cent Mn,

$$305 \times .80 = 244 \text{ lbs. Mn};$$

third, carbon from both the FeSi and FeMn,

$$792 \times .015 = 11.88$$
$$305 \times .055 = 16.77$$
$$\overline{28.65 \text{ lbs. C.}}$$

Taking into account the residual silicon, manganese and carbon

of the bath, and adding to them those furnished by the FeSi and FeMn, there will be,

$$
\begin{aligned}
&\text{Total Available} \\
&\text{Lbs.}
\end{aligned}
$$

$$
\begin{aligned}
\text{Si} &= .0001 \times 24{,}000 + 79.2 = 81.6 \\
\text{Mn} &= .0003 \times 24{,}000 + 244.0 = 251.2 \\
\text{C} &= .0012 \times 24{,}000 + 28.7 = 57.5
\end{aligned}
$$

With the pounds of the several elements divided by the weight of the charge, there will be found the approximate analysis of the finished product:

$$
\begin{aligned}
100 \times 81.6 \div 24{,}000 &= .34 \text{ per cent Si} \\
100 \times 251.2 \div 24{,}000 &= 1.05 \text{ per cent Mn} \\
100 \times 57.5 \div 24{,}000 &= .24 \text{ per cent C}
\end{aligned}
$$

or, calculating another way, the approximate composition can be determined in finished product using the same quantities of values in terms of available silicon, manganese and carbon:

$$
\frac{100 \times 79.2}{24{,}000} + \overset{\text{Residual}}{.01} = .34 \text{ per cent Si}
$$

$$
\frac{100 \times 244}{24{,}000} + .03 = 1.05 \text{ per cent Mn}
$$

$$
\frac{100 \times 28.65}{24{,}000} + .12 = .24 \text{ per cent C}
$$

In making the foregoing computations the amounts of sulphur and phosphorus have been ignored. With a slag highly charged with silica no absorption of these takes place, and the amount of either carried in by the melting stock nearly equals the finished product in regard to their content. Usually there are slight gains. The sulphur increases because of flame contamination and a loss of metallic iron by oxidation. Phosphorus also increases slightly through the latter cause. Both may be slightly augmented by movements from the deoxidizers.

The chemical composition as shown in the foregoing figures will differ from that shown by the ultimate analysis of a sample taken when the steel is going into the molds. Comparing the approximate and ultimate figures we find:

	Approximate Analysis	Ultimate Analysis
C	.24 per cent	.22 per cent
Mn	1.05 ,, ,,	.71 ,, ,,
Si	.34 ,, ,,	.31 ,, ,,

The main difference is between the manganese added and that found, the cause of which will be understood in the explanation of the purpose in using the deoxidizing agents FeSi and FeMn. During the second stage of the conversion the bath of molten metal carried variable quantities of dissolved ferrous oxide (FeO) and with that substance there was a vigorous chemical action between the carbon and the oxygen of the FeO, producing copious bubbles throughout the bath of the gas CO. So long as the bath remained liquid this chemical action would go on, charging it with that gaseous body. Were the metal in that condition to be poured into castings, they would be found to be unsound or honeycombed with blow holes.

Since solidity of product is one of the objects sought in the physical properties, recourse must be had to some agent or agents that will remove the gas-forming action in the bath of metal before it can be drawn off. The agents must possess greater affinity for the oxygen of the dissolved FeO than the carbon in intimate association with it. Practical experience has shown that manganese and silicon accomplish the purpose and those elements are commercially available in the alloys FeMn and FeSi, hence their designation as deoxidizers. The functions may be expressed as follows:

$$(1)\quad FeO + Mn = Fe + MnO_2.$$
$$(2)\quad 2FeO + Si = Fe_2 + SiO_2.$$
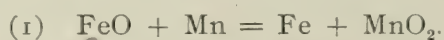
In the interchange between the C and the FeO we have a gas impregnating the bath. In the interchange, as shown in the above equations, we have a solid or an easily fusible slag formed by the SiO_2 and the MnO, which, being lighter than the molten metal, quickly floats to the surface of the bath. Thus with normal conditions the metal will cease bubbling and pour quiet or " dead " and tend to make solid castings.

The amounts of silicon and manganese in the finished metal will in the main depend upon the condition of the bath at the time the deoxidizers are added, and the differences in analyses between the approximate and ultimate figures may be taken to represent the amount consumed in " washing " the bath of metal.

The usual practice in adding the deoxidizers is as follows: The carbon having dropped to say .10 to .12 per cent, the dose of FeSi, broken into short pigs, is placed on the breast of the

furnace in order to heat it up before pushing it into the bath. After a lapse of about eight minutes the whole is pushed into the bath, allowing a little time to pass during which the FeSi is melting and dissolving. To insure a complete distribution the bath is agitated with bars of iron. Ten minutes after the FeSi is added the metal is ready to tap, but before doing so the dose of FeMn is thrown in and then the tapping may take place. It is sometimes the practice to put part of the FeMn into the furnace and part into the ladle, the latter being done while the steel is flowing into it.

In an acid heat the losses of silicon in the act of deoxidizing are not great, but with the manganese for the same purpose considerable is consumed, being greater when entirely added to the furnace than when divided between the furnace and ladle. For that reason it is necessary to make allowances for such losses when calculating the necessary dose. Further, the losses are greater using oil for fuel than with gas, the latter flame being " soft " and the former sharp. An oil flame may be likened to a blowpipe and its effect always strongly oxidizing.

As already shown, silicon will reduce the FeO, but the reduction is not always complete, and what may escape the silicon may further unite with manganese. Hence the reason for simultaneously using two powerful and active reducing agents. The influence of the two agents remaining in the finished steel after their reducing function will be considered later.

The yield of metal after conversion against the weight charged is a variable one and depends upon the character of stock and manipulation. If the stock, other than the pig iron, should be of light, thin sections, there will be a heavy melting loss due to excessive burning or oxidizing. If the flame should be very sharp during the melting period the same condition will arise. The melting losses are also heavier on oil fuel than on gas for the reason as stated. Not only will the conditions (when abnormal) result in heavy melting losses, but the effect will be seen in certain physical properties of the product. That is to say, " over-oxidizing " from any cause is bad practice; yet even with a greater tendency towards " over-oxidizing " following the use of oil, the condition is still subject to control. To express the losses in figures to represent the difference between metal charged and that yielded is not so easy, but it may be found to be about 5 per cent.

The principal points about the manipulation of an acid heat may be given as follows:

1. To charge enough pig iron so that there will be a high enough initial carbon to insure an easily maintained fluidity of bath. A low percentage of pig iron will mean a rapid heat, but at the sacrifice of quality and a very high flame temperature. The less carbon charged, the greater the chances of over-oxidizing.

2. Charge as heavy sections of scrap as possible and protect it as far as possible from burning with a covering of pig iron.

3. Watch flame conditions to guard against undue burning of stock. This point calls for a high degree of skill to maintain flame conditions and yet reach the thermal ranges necessary to melt the stock.

4. Be judicious in oreing heats. Too much ore is harmful.

5. Aim for uniformity in product in a given class of work.

6. Over-anxiety for tonnage will make the scrap pile grow.

NOTES ON METALS AND THEIR FERRO-ALLOYS USED IN THE MANUFACTURE OF ALLOY STEELS *

By O. J. STEINHART, F. C. S.

IN these notes it is the writer's intention to place before those generally interested in metallurgy some particulars he has been able to collect over a period of several years, during which he has been studying this subject. The knowledge acquired is partly the outcome of actual manufacturing experience and partly from data kindly supplied by some of the leading works and metallurgists.

The present-day requirements of steel makers, with respect to the purity of the elements they add to the various steels, are most stringent and exacting, and those intending to evolve a new method, or wishing to add another metal or alloy to the already not inconsiderable list of the latter, should bear this in mind. The fatal effects which very small quantities of such elements as sulphur, phosphorus, etc., have upon steels form such elementary knowledge that it goes without saying that

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* Abstract of a paper read before the Institution of Mining and Metallurgy, on January 18, 1906. — " Iron and Coal Trades Review," January 26, 1906.

none of these should be present to any appreciable extent in the materials added to the steel. Another point often overlooked by novices is the presence of several per cents of carbon, so often found with electric-furnace products, which are as undesirable as the other impurities just referred to. Therefore, generally speaking, the freer the metals and alloys are from these interfering substances the more welcome they will be to the steel maker, and the better will be the prices paid by him.

The metals and their ferro-alloys used by steel makers, in the order of their consumption and importance, are probably as follows: Manganese,* nickel, chrome, tungsten, molybdenum, vanadium, and also experimentally, cobalt, titanium, uranium and, recently, tantalum.

NICKEL

This most important metal is derived mainly from two important classes of ore:

1. Garnierite, a hydrous silicate of nickel and magnesia, according to T. Moore, of the composition $7 NiO\ 6 SiO_2\ H_2O$, discovered in 1867 by J. Garnier in New Caledonia and named after him. The output of this ore from small beginnings has assumed very large proportions, and in 1902 over 120,000 tons were shipped to various smelters and refiners. Although lately the production has somewhat fallen off, owing to the exploitation of the Canadian mines, it is probably not very much less now, 65,000 tons being produced for the first half of 1905. The ore now and again tests as much as 30 to 40 per cent of nickel, but the average grade shipped is about 7 per cent (dried at 100° C.); occasionally consignments as low as 5 per cent have been exported. Moisture varies according to circumstances between 18 per cent and 30 per cent. The value of such an ore in New Caledonia, provided it tests over 7 per cent metallic nickel, is about 70 centimes per k. of metallic nickel contained, with a corresponding increase for material of a higher percentage. For instance, an ore of 10 per cent is worth approximately 1 franc per k. nickel contents. The greater value of higher grade ore is easily accounted for by the fact that it takes about 15 to

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* The ferro-alloys of manganese and also silicon will not be dealt with here, as so much valuable information has been given by Hadfield, Keller and others, to be found in the " Proceedings " of the Iron and Steel Institute.

16 tons of a 7 per cent ore to produce 1 ton of refined nickel (99 per cent), and the freight from New Caledonia to Europe is considerable, varying from 25s. to 30s. per ton (with 18 per cent to 30 per cent moisture).

2. Nickeliferous pyrrhotite and chalcopyrite. With the exception of a formerly somewhat important mining operation in Norway and Sweden, practically all the ore comes from the nickel and copper district of Sudbury, Ontario. The average amount of nickel is about 3 per cent, and that of copper under 2 per cent. From the Dominion Geological Survey the writer has computed the following in round figures: 1902, ore raised, 270,000 tons; ore smelted, 233,000 tons; average percentage of Ni, 2.55 — Cu, 1.78 per cent; 1903, ore raised, 153,000 tons; ore smelted, 220,000 tons; average percentage of Ni, 3.16 — Cu, 1.81 per cent. Over 300,000 tons were mined in 1905.

The Scandinavian supply above mentioned never amounted to much, and since 1891, when 125 tons of nickel were produced, it has dwindled away into insignificance.

With regard to the cost of manufacture of nickel from the usual 7 per cent Garnierite ore, the following figures, obtained from private sources, may be taken as fairly correct per ton of marketable metal:

Smelting and Bessemerizing	£45
Grinding and calcining	5
Reducing	5
	£55

This, naturally, does not include cost of ore and freight to Europe and standing charges of works, which should amount to another £60 to £80 per ton, making a total of, say, £120 to £130 per ton of metal.

Chrome

The only important ore forming the raw material for the manufacture of the above metal and its ferro-alloys is chrome iron ore, or chromite, represented in the pure state by the formula FeO, Cr_2O_3, containing 68 per cent chromic oxide. Often, however, the ferrous oxide is replaced by magnesia and the chromic oxide and alumina, and it generally contains variable quantities of silica. It is found in Asia Minor, New Caledonia, Greece, New South Wales, Canada, and the United States of

America, etc. The chief producers have been Asia Minor and New Caledonia, the former source several years back supplying 40,000 tons per annum, and the latter about the same amount for 1904. Probably the total yearly output from all sources is about 70,000 tons, by far the greater portion of which, however, is employed for the manufacture of chromates and bichromates, and refractory furnace linings.

Ores for the production of ferro-chrome should be as pure as possible and free from silica, as the latter element has a tendency to enter into the alloy instead of going into the slag, when smelted in the electric furnace. A suitable ore which should contain at least 50 per cent of Cr_2O_3 is easily obtainable; New Caledonian ores of 56 per cent are by no means uncommon. They can be bought for about 70s. per ton, at a convenient English or Continental port, with a corresponding increase in price for each unit above 50 per cent. The price of the ore has gradually gone down; for instance, in 1893 it was 110s. per ton. Only the higher grade purer ores are suitable for the manufacture of good ferro-chrome.

The cost of the manufacture of ferro-chrome (60 per cent to 70 per cent) is difficult to arrive at, and will naturally vary according to the cost of power, but, taking the figure given by R. S. Hutton at 1.21 horse-power per annum for 1 ton of the alloy, we arrive at the following:

	s.
2 tons of chromite (50 per cent) at 70s. equal	140
1.2 h. p. years at 80s. . . . . ,,	96
Wear and tear, electrodes, labor, etc. . . . . . ,,	30
	266

We thus see that the ordinary ferro-chrome with about 6 per cent to 8 per cent of carbon can be made for, say, £15 per ton, not including general expenses. It is selling at prices varying between £23 to £30 per ton on a 60 per cent basis of chromium, according to carbon contents and purity.

TUNGSTEN

Tungsten has become of renewed interest within the last five years, owing to its wide and successful application for the manufacture of so-called self-hardening rapid-tool steels. Its chief ores are wolframite, $FeWO_4$, in which some of the iron is often partly replaced by manganese, hübernite, $MnWO_4$ and

scheelite, $CaWO_4$. The ore most suitable for the production of the metal is wolframite. Although found in many places, such as Queensland, New South Wales, Straits Settlements, Bohemia, Cornwall, Spain, United States of America, etc., it does not occur in large masses and is often very pocketty. In the pure state it should contain over 70 per cent WO_3, but such ores are not plentiful, and the average grade runs between 60 per cent and 70 per cent tungstic acid, WO_3.

The presence of wolfram in the tin ores at one time caused great trouble, and, although Oxland, in 1857, found a convenient method of separating these two metals by means of fusion with sulphate or carbonate of soda, which rendered the WO_3 soluble as Na_2WO_4 and left the tin behind, it was not until the system of electro-magnetic separation was applied to these mixed ores that the problem was satisfactorily solved. The San Finx Tin Mines in Spain were probably the first to avail themselves of this method, and shortly afterwards the Clitters United Mines in Cornwall followed suit, and now the separation of the magnetic wolfram from the non-magnetic tin-stone offers no serious difficulty if intelligently applied.

The ores, whether dressed in the ordinary manner or electro-magnetically separated, should be as free as possible from tin, arsenic, sulphur and phosphorus, otherwise these impurities are apt to find their way into the metal made from them. The ore is sold on the basis of its WO_3 contents. At the present moment it is about 25s. to 27s. per unit of WO_3; thus a 65 per cent ore is worth about £85 per ton. The prices of the ore have varied in an extraordinary manner; at one time it could be bought for £15 per ton, and last year it went as high as £150 per ton.

The world's production of wolfram is about 3,000 tons per annum, based on 60 per cent to 65 per cent ore; Queensland seems to have been the chief producer in 1904, with 1,538 tons, valued at £161,635; next probably came Spain and Portugal, with about 400 to 500 tons.

Without going fully into the cost of the manufacture of tungsten, it may be taken to be between £80 and £100 per ton of metal made, including the manufacturer's profit. The yield is by no means a theoretical one, as it requires from 140 to 145 units WO_3, as compared with a theoretical consumption of 120 units, to produce 100 parts of 96 per cent to 98 per cent tungsten.

If we, therefore, take the present price of ore to be 26s. per unit, we have the following: 26s. × 140 + £90 = £272 per ton. This is about the present price of the metal, which is regulated by the value of the ore. At one time, when the ore was 40s. a unit, the metal was worth over £400 per ton; it was, however, as low as £140 per ton four years ago.

MOLYBDENUM

In many respects molybdenum resembles tungsten, belonging to the same group of elements. It is used for similar purposes as tungsten, though not nearly so extensively, one of the reasons being that it is more difficult to prepare in the pure state, and that its ores do not occur very plentifully. The effect it has upon steel is by no means finally settled, and though it is said to be from two to three times as powerful in its action as tungsten, it is not to be relied upon to the same extent, as it is more difficult to alloy with steel, because of its liability to oxidize and volatilize.

The chief ores of molybdenum are molybdenite, MoS_2, and wulfenite, $PbMoO_4$, both of which are comparatively rare minerals. In the pure state it contains 60 per cent of the metal and 40 per cent of S, and if testing 90 per cent to 95 per cent, MoS_2 is worth from 1s. to 1s. 3d. per pound. Parcels are often sold cheaper, as there really is no fixed price for the mineral, sales generally being a matter of negotiation, as is the case with so many of the rarer minerals.

According to some manufacturers, wulfenite is the best raw material for the preparation of suitable metal. It is first melted with soda ash and carbon, resulting in the formation of metallic lead and a fused mass of molybdate or soda, from which molybdic acid is separated. The latter is then reduced with carbon in crucibles very much like tungsten, yielding a gray, metallic powder of about 95 per cent purity, with 2 per cent to 3 per cent carbon, and a considerable quantity of undecomposed oxides, by no means an ideal product.

The present price of metallic molybdenum, either as metal or in the form of a ferro-alloy, is about 5s. to 6s. per pound.

VANADIUM

This rare metal has come into prominence within the last four or five years, on account of the great increase in tensile

strength, elasticity and ductility it imparts to steel when added only to the extent of about 0.2 per cent to 0.5 per cent. Its most important ore is vanadinite, or chloro-vanadate of lead, represented by the formula: $3(Pb_3V_2O_8) + PbCl_2$. In the pure state it should contain 19.35 per cent V_2O_5, but the ores actually used for the manufacture of ferro-vanadium generally only contain in the neighborhood of 10 per cent V_2O_5. Such an ore is worth about 4s. to 5s. per k. of V_2O_5 contents, assuming that it tests over 10 per cent.

The metal is found in quite a number of rare minerals, such as dechenite ($PboV_2O_5$), vanadite (pyrovanadate of lead and zinc), carnotite, etc. The ash obtained from anthracite, found at Yauli, in Peru, is said to contain as much as 25 per cent of V_2O_5. Vanadium ores are found in limited quantities in Spain, the Argentine Republic, Mexico, Sweden and formerly in Cheshire (near Alderley Edge).

Titanium, Cobalt, Uranium, Tantalum

There is very little information obtainable with regard to the above elements. Titanium, perhaps, deserves rather more attention than the rest, chiefly owing to the work A. Rossi has done in this direction. He reduces rutile (chiefly TiO_2) and iron in the electric furnace with the aid of aluminum, and employs the resulting ferro-titanium (10 per cent to 12 per cent Ti) for increasing the tensile strength of cast iron.

Cobalt is said to be used for similar purposes as nickel, but unless it offers material advantages over the latter, the much higher price it commands would at once restrict its application.

Ferro-uranium has been made experimentally and tried for steels, but it is at present far too costly.

Tantalum has recently come into prominence in connection with a new incandescent lamp brought out by Messrs. Siemens, of Berlin, in conjunction with Von Bolten, and experiments have also been made to use it for similar purposes as tungsten and molybdenum, but before it can claim any serious attention its price must be reduced very materially.

ELECTRIC SMELTING OF MAGNETITE ORES *

Incentive to Commerce

THE iron and steel industries," said Dr. Haanel, " are the foundation of our modern civilization. To realize our dependence upon them, try to imagine what the state of affairs would be if our iron and steel industries were swept away. Transportation by railway and by boat, as we have it to-day, would cease, the machinery in our factories would be banished and the comforts and luxuries of our life destroyed. We might better do without gold or silver than this much cheaper metal."

The commercial status of a nation, he continued, depended largely upon the development of the iron and steel industries. Not speaking of England, which was the pioneer in this work, Germany and the United States, to a great extent, owed their prestige to the development of their iron and steel industries.

The country which required to import its iron ore was handicapped in the race for commercial supremacy. In the fiscal year of 1903 and 1904 Canada had imported pig iron to the value of $43,000,000. Thus was Canada dependent on other nations for a material necessary in every industry.

In Canada, which was the Eldorado attracting a teeming population, the need for iron was increasing to provide tools and agricultural implements for the new settlers, structural material for railways, boats and bridges, and material for the modification of established and the inauguration of industries. To stimulate and encourage production of iron and steel from abundant raw material, the government had given generous bounties and imposed import duties.

The distribution of the raw material in Canada was peculiar, while the necessary coking coals for blast furnaces were found at the extreme east and west. In Ontario, Quebec, Saskatchewan and Alberta were large ore deposits, but not coal deposits capable of furnishing coke for metallurgical purposes. If these deposits were to be used by processes of production at present in

* An address delivered by Dr. Eugene Haanel, Dominion Superintendent of Mines, before the Canadian Club, Toronto, March 12, 1906. " The Canadian Engineer," April, 1906.

use, coke would have to be brought to blast furnaces erected in the vicinity of the mine, or the ore transported to blast furnaces near the base of the coke supply. The heavy transportation costs made the process uneconomical.

Deeply impressed with the desirability under which the country rested in regard to the upbuilding of a steel industry, on entering his present position Dr. Haanel set himself to finding some other method or some other source of energy than the combustion of carbon in blast furnaces. Unless a new method could be proven to be practicable, immense ore deposits must remain undeveloped and regions remain waste which might otherwise teem with a vast industrial population.

The Electric Process

The electric process had been profitably employed in different parts of Europe, especially France. " In the solution of the problem of applying electric energy to the extraction of metals from their ores, Captain Stassano in Italy and Héroult and Keller in France had rendered conspicuous service. It was seen that if by the electric process pig iron could be economically produced, such countries as Brazil, Chili, Sweden, Norway, Finland and Canada, all rich in iron ore deposits, and possessing extensive water powers, but lacking coal, would be able to render themselves independent of outside sources by employing the electro-thermic process of manufactures of their iron and steel.

" It was with a view of ascertaining the practicability of introducing electric smelting into Canada that the Hon. Clifford Sifton, then Minister of the Interior, appointed a commission to investigate this subject, results of which have been laid down in a special report.

" The only experiments which the commission was able to witness in the electric smelting of iron ores were those made by Dr. Héroult at La Praz, France, and Mr. Keller, of Keller, Leleux & Co., at Livet. The first was a mere trial; the latter more extensive experiments continued for a number of days, but were made in furnaces not designed for the production of pig iron, but in furnaces which had been constructed for the production of ferro-silicon. The ore used in the Livet experiments had been imported for that purpose from Spain, and was an excellent

hematite, very porous, free from sulphur, and containing a considerable percentage of manganese, consequently an ore easily treated in regard to sulphur and also easily reduced.

" The output of pig iron per 1,000 electric horse-power days was for one set of experiments equal to 5.76 tons; for second set of experiments it was equal to 12.12 tons; but the iron made in this last experiment was mainly white iron. Mr. Harbord, the metallurgist of the commission, adopted as the probable output 1,000 electric horse-power days, the mean of the two experiments, namely, 7.82 tons.

" Not alone was this discrepancy between the two experiments very satisfactory regarding the absorption of electric energy required per ton of pig produced, but a number of points requiring determination for our Canadian ores, such as the successful smelting of magnetite, the utilization of iron ore of high sulphur content, and the substitution of charcoal for coke, required to be demonstrated.

" As a matter of fact, an experiment was made at Livet with the substitution of charcoal for coke, which proved an absolute failure, and it was assumed by Mr. Harbord and Mr. Keller that charcoal could be used only if it was first briquetted with the ore, and the briquette broken up the size of one-inch cubes.

" Regarding the electric smelting of iron ores of high sulphur content, Mr. Harbord states that the experiments cannot be said to have demonstrated that low sulphur pig iron can be obtained without manganese in the ore mixture, and before this can be considered experimentally proved, it will be necessary to have a series of experiments made with non-manganiferous ores.

" For the successful introduction of electric smelting of Canadian ores, the following points which could not be settled by the European experiments require demonstration:

" Could magnetite, which is our chief ore, and which to some extent is a conductor of electricity, be successfully smelted?

" Could iron ores with considerable sulphur contents be made into pig iron of marketable composition?

" Could charcoal, which can be made from mill refuse and other available sources of wood useless for other purposes, be substituted for coke, which must be imported?

" And, lastly, what was the exact amount of electric energy required per ton of pig iron produced?

" With a view of ascertaining these important facts experimentally, I prepared a memorandum to the Hon. Mr. Oliver, Minister of the Interior, reccmmending an appropriation for the investigation of the whole subject.

" It was fortunate that Dr. Héroult, of La Praz, who had been the first to experiment on the subject of electric smelting of iron ores, happened at that time to be on a visit in Ottawa. He signified his consent, if the appropriation were made, to undertake the designing of a furnace of about 250 horse-power capacity, and the investigation of the factors entering into the economic production of pig iron from Canadian iron ores by the electro-thermic process.

" The Lake Superior Power Company of Sault Ste. Marie cffered a building in which to erect the plant, and the use of one of their alternators of 300 electric horse-power capacity, free of expense for four months. It was decided to accept this offer, and the plant was ordered to be erected in the building provided for this purpose.

" The necessary transformer to transform the current down from 2,200 volts to about 400, such as was required for our experiments, and the necessary measuring instruments to determine the power consumed, were ordered from the Westinghouse Company, and electrodes 6 feet long and 16 inches square section were ordered from Sweden. The construction of bins, overhead work of the furnace, construction and erection of furnace and experimentation to adjust the capacity of the crucible of the furnace to the power available consumed the greater part of the fall and winter."

Tried at the Soo

The experimentation on Canadian ores began in earnest the middle of February, the furnace being in operation night and day, with some intermissions, until March 5. During that time about 150 casts were made, yielding about 55 tons of pig iron. For the first experiments the ores employed were hematite, such as used by the Algoma Steel Company in their blast furnaces; for the remainder of the experiments different classes of Canadian magnetite, from the different sources of supply, all of

high sulphur content, with the exception of the Wilbur magnetite, which was low in sulphur, were employed.

" From theoretical grounds, much difficulty was expected to be encountered in the smelting of magnetite. This can be best understood by describing to you the construction of the furnace, which, you will perceive, is exceedingly simple."

The Furnace Described

Dr. Haanel used a glass to describe the furnace, explaining that the walls are lined with fire brick, the bottom with carbon, and that just above this carbon lining is the tapping hole; whilst higher up is another hole for floating off the slag. In this crucible the ore is placed and a suspended carbon electrode 6 feet long by 16 inches square (imported from Sweden) is inserted therein. An electric current is passed through the electrode into the ore. Now, whenever the electric current meets with resistance, it is changed into heat. In this case the electric current sent through the electrode is stopped by the ore in the crucible, and the heat generated from this resistance reduces the ore from a mineral condition into a metallic state. Charcoal is the reducing material, and the iron is melted to the bottom of the crucible, when it is tapped out and run into pig-iron molds, as in blast-furnace practice.

" The regulation temperature is maintained by a man who looks after the instrument and moves the electrode, but this is only in the experimental stage. When it is put to commercial utility this regulation will be automatic."

Charcoal Displaces Coke

Even the first experiments with magnetite showed that our fears had been groundless and that magnetite could be smelted with as much facility as hematite, and with an output equal to that of the best experiment made with hematite.

" Moreover, since it was important to substitute, if possible, charcoal, which can be cheaply produced in Canada, for coke — which is costly and must be imported — the charges were made with charcoal. No difficulty was experienced, the furnace working quietly and regularly, requiring little attention or regulation of the electrodes.

" Analysis of the iron produced soon proved that although

the slag was not particularly basic, the sulphur could be caused to pass into the slag, resulting in a pig iron containing a few thousandths of 1 per cent of sulphur.

" In every instance the output was far greater, in several instances one third greater, than the figures adopted by Mr. Harbord, in the report of the Commission on Electric Smelting."

Experiments with roasted and briquetted nickeliferous pyrrhotite, containing 1.6 per cent of sulphur, were equally successful, furnishing a ferro-nickel iron pig, containing $4\frac{1}{2}$ per cent of nickel and about 0.006 sulphur. The estimated value of this product was $40 to $44 a ton. So successful have these experiments proven that the Lake Superior Power Corporation have decided to acquire the government plant for the purpose of converting their stock of briquetted ore into marketable ferro-nickel pig.

Electrode Waste Insignificant

" One of the most important points in the investigation which could not be successfully settled by the experiments at Livet was the consumption of the electrodes, and it was found that the consumption was beyond expectation low, and that an electrode which had been in use for three weeks, and during that time had been exposed to free air in an incandescent state for many hours and had been used for melting down charges, which is always attended by waste of electrode without corresponding output in metal, that even with this severe test, the consumption per ton of pig iron produced was only 15 to 20 pounds." According to Dr. Héroult's estimates, this means an electrode outlay of 30 cents per ton of pig iron, instead of 77 cents as heretofore. One pound costs $1\frac{1}{2}$ cents."

Poor Ores Made Valuable

" Many of our magnetites are too high in sulphur to be handled by the blast furnaces, and consequently have so far been of no commercial value. But the very best of pig iron, as has been proven, can be made from ores which contain as high as 1 per cent of sulphur. A blast furnace will not usually handle an ore which contains one tenth of 1 per cent of sulphur, and requires, therefore, an ore which can be got at a low sulphur figure. The Algoma Steel Works pay, I understand, $4.50 for

the hematite ore which they use in their blast furnaces. A pig iron equal in value and lower in sulphur contents, can be made by the electric process from sulphur ores, which can be bought for $1.25.''

ORE LANDS AND WATER POWER CONTIGUOUS

" Regarding water-power required for the application of this process, it may be stated that many water-powers exist in Ontario surrounded by iron ore fields in localities ill-adapted for the application of electric energy for any other purpose, and could be developed to furnish an electric horse-power a year from $4.50 to $6.

" With such a price for the energy required, the small consumption of electrode, the cheapness of ore employed and the peculiar excellence of the pig iron produced, electric smelting of iron ores in Canada, using charcoal or peat coke, made from our peat bogs of enormous extent, may be pronounced a commercial success. Under the prevailing conditions in Canada it now only remains for the engineer to design a plant on a commercial scale, say of 100 to 150 tons daily output, with all the necessary labor-saving appliances. Just as in the case of the blast furnaces, so likewise with the electric furnace, experience gained will result in further economy, and the day may not be far distant when the carbon monoxide, which is of high calorific value, and which, at present, as a product of the reaction taking place in the electric furnace, is allowed to escape without utilization, will be employed for increasing the output by at least a third or half. If that should take place, the blast furnace could not compete with the electric furnace even under the conditions where coke might be cheaper than at present quoted in Ontario and Quebec.''

ELECTRIC FURNACE INEXPENSIVE

" A further advantage of the electric process is that the units employed are comparatively small and cheap of construction. A unit of 1,500 horse-power is, perhaps, the largest that under present circumstances should be constructed. Such a unit would have an output of 18 tons per day, and corresponds in size to about the larger Swedish charcoal blast furnace.

With the present advance which has been made in the transference of electric energy, batteries of electric furnaces could be set up at various iron ore deposits which could be fed with electric energy from some centrally located water-power, thus effecting a saving of the transportation costs of the ore from the mine to the furnace.

" When a deposit is worked out, the furnaces may be moved to the next deposit, simply lengthening the wires which carry the high-tension current to the transformer of the plant."

This method is especially applicable in the case of the many pocketty deposits of magnetite which occur in the Ottawa Valley.

Successful Results of Experiments

" The following is a summary of the results of experiments which have been completed under government auspices at Sault Ste. Marie:

" 1. Canadian ores, chiefly magnetite, can be economically smelted by the electro-thermic process.

" 2. Ores of high sulphur content can be made into pig iron containing only a few thousandths of sulphur.

" 3. The silicon content can be varied as required for the class of pig to be produced.

" 4. Charcoal, which can be cheaply produced from mill refuse or wood, which could not otherwise be utilized, and peat coke made from peat, of which there are abundant deposits in Ontario and Quebec, can be substituted for coke without being briquetted with the ore.

" 5. A ferro-nickel pig can be produced, practically free from sulphur and of fine quality, from roasted nickel-ferro-pyrrhotite.

" 6. Pyrite cinders, resulting from the roasting of pyrite in the manufacture of sulphuric acid, and which at present constitute a waste product, can be smelted into pig iron by the electric process.

" 7. Titaniferous iron ores, containing up to 5 per cent, can be successfully treated by the electro-thermic process.

" The last conclusion is based upon an experiment made with an ore containing 35 per cent of titanic acid, yielding a pig iron of passable quality, judging from its fracture."

What It Means to Canada

" The result of the introduction of electric smelting into Canada may be summarized as follows:

" 1. The utilization of our extensive water-powers, which cannot, at present, be profitably employed for any other purpose.

" 2. The utilization of the large number of iron ore deposits which, on account of their high sulphur content, cannot be treated by a blast furnace, and have so far been valueless. A consideration of extreme importance, for already the question has arisen how long the present supply of blast-furnace iron ore is likely to last, and ores are now accepted by furnace men with a metallic content such as would not have been looked at a few years ago, and when these ores are exhausted and none but sulphurous ores or titaniferous ores are available, the stacks of the numerous blast furnaces, which have rendered such magnificent service to our present civilization, will be silent and smokeless, having been supplanted by the electric furnace, which can successfully treat an ore which the blast furnace cannot handle.

" 3. The utilization of our extensive peat bogs for the production of peat coke, to be used as reducing material for the operation of electric furnaces, and the utilization of mill refuse and sawdust, for which there has been so far no practical use.

" 4. Rendering it unnecessary for Canada to import fuel for metallurgical processes.

" 5. Enabling Canada to produce her own pig iron from her abundant resources for home consumption, and consequently retaining in her own country the money which otherwise would have to be sent abroad to purchase pig iron in the crude and manufactured state.

" 6. The development of steel plants and rolling mills using only electric energy."

The Best Crucible Steel

" It is only a year since the report of the commission appointed to investigate the different electrothermic processes for the smelting of iron ores and the making of steel, in operation in Europe, was sent out to the public, but already a steel plant adopting Héroult's system has been erected in Syracuse,

N. Y., and will be in operation in about two weeks; another, using the Kjellin system, has been erected in Sheffield, England, and I have been notified that two of the Kjellin system and one Héroult have been erected in Germany. These furnaces are designed to make the best crucible steel, and their introduction means the abandonment of the old crucible process. I see no difficulty in the way of constructing electric furnaces of a capacity equal to that of our open-hearth furnaces, and the production of structural steel by the electric process is likely to become an accomplished fact in the near future."

Realization beyond Expectation

" I need not picture to you the future which opens a vista of commercial success for Canada by the inauguration of the new metallurgy of iron and steel, on account of the magnificent asset of her abundant supply of water-power. I remember having delivered in Faraday Hall, Victoria University, Cobourg, shortly after the invention of the telephone, a lecture in which I tried to picture the results of the discoveries which had been made in the practical application of that wonderful agency we term electricity, and while what I said seemed greatly to interest the audience, the outcome of the lecture was the pronouncement that certainly the lecturer possessed a brilliant imagination. But when I look back at what I said, how feebly and inadequately did I describe what might take place, and the twenty years that have elapsed have shown a progress such as I could not have imagined, so much greater has been the final outcome than the feeble prophecy ventured by me to the audience on the occasion named. But in the matter of electric smelting we do not draw upon the imagination, but present to you hard facts and well-established figures."

Appeal to Capital

" To reap the benefits of the experiments made at Sault Ste. Marie means intelligent enterprise in the expenditure of capital. The government has furnished you with facts on which to base a sound judgment as to the feasibility of commercially engaging in the manufacture of pig iron by the electric process; with that its duty to the nation is done; it remains with you business men to apply, perfect and profit."

THE PRESERVATION OF IRON AND STEEL *

By B. H. THWAITE, C. E.

MORE than a quarter of a century ago the writer stated the opinion " that one of the most dangerous forms of construction was that in which reliance for structural strength depended upon unprotected metals."

In consequence of the partial collapse of the Charing Cross Station roof, considerable attention has been directed towards the condition of similar structures, and doubts are openly expressed as to the advisability of employing iron and steel so freely in the future as these metals have been employed in the past. It is always unwise to draw general conclusions from an isolated experience, and such a course is particularly to be deprecated in the case of the Charing Cross disaster, although this occurrence will doubtless furnish useful lessons when all attendant circumstances are fully known and analyzed.

The object of the present article is to consider the effects of corrosion upon iron and steel and to discuss methods by which the permanence of structures in which these materials are used may be extended by the application of preservative methods.

THE CHEMICAL ASPECT OF CORROSION

When iron or steel is exposed to the influence of air containing water vapor and acids the process of decay, generally described as oxidation or rusting, is commenced.

For the production of rust three substances are necessary: oxygen, aqueous vapor and an acid, and the intensity of the action depends upon the proportion of aqueous and acid vapors contained in the air. The rusting of iron takes place in two stages, and as carbon dioxide is the acid most generally present, the nature of the reactions may be thus expressed:

$$(1) \quad Fe + H_2O + CO_2 = FeCO_3 + H_2.$$
$$(2) \quad 2FeCO_3 + 3H_2O + O = Fe_2H_6O_6 + 2CO_2.$$
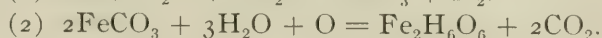
In the first stage, water and carbon dioxide produce carbonate of iron concurrently with the liberation of hydrogen,

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* " Concrete and Constructional Engineering."

and in the second stage the carbonate of iron combines with water and oxygen to form ferric hydrate, or rust, the carbon dioxide being set free.

The above equations do not precisely express the chemical changes taking place, because iron rust is not pure ferric hydrate, and its composition is further complicated by the occurrence of mineral acids, such as the oxides of sulphur in the atmosphere. But the explanation is sufficient to give a general idea of the process.

Thermal effect may displace that of an acid — for instance, when iron or steel is exposed to heated air oxidation proceeds in two stages, which may be expressed as follows:

$$(1) \quad 2Fe + O_3 \text{ of] air} = 2FeO + O.$$
$$(2) \quad 2FeO + O = Fe_2O_3.$$
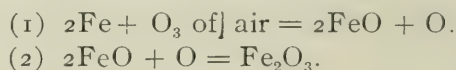
When superheated steam is present a third form of oxidation is produced, that is, magnetic oxide or forge scale, Fe_3O_4, thus:

$$3Fe + 4H_2O \text{ (superheated steam)} = Fe_3O_4 + 8H.$$

The effect of oxidation is not only destructive to the integrity of the metal, but it may also have a disruptive influence. For instance, an iron band or tie-rod encircling or penetrating masonry may disrupt or fracture such masonry by increase in the mass of the tie-rod or band as the result of the oxidation of the metal.

Examination of the expression FeH_6O_6 shows that each atom of metallic iron converted to rust is in combination with twelve atoms of hydrogen and oxygen. It is also easy to realize that the consequent increase of bulk is very great, and represents a practically irresistible force. In fact, it was the enlargement of iron ties in the same way that nearly destroyed the famous façade of St. Mark's, Venice.

To illustrate the destructive effects of the oxidation of metals, let us take the case of an unprotected wrought-iron lattice bar, 4 inches by 1 inch, exposed to the air of a city, in which the aqueous proportion of the atmosphere is high, as are most of the towns in which moisture is added by the burning of hydro-carbonaceous coals. Calculating by the writer's formula given in Molesworth, it will be found that the complete oxidation of the whole of the metal will require one hundred

and ten years, so that in a period of fifty-five years only one half the original material will remain. In situations where the metal is exposed to specially destructive gases the process of decay may be still more rapid. For example, it is said that some parts of the iron work at Charing Cross Station have already been reduced to less than one half the original thickness, after less than forty-five years' service, and in spite of paint.

Such a statement permits one to realize the extent of the undermining influence of rusting action during a period of years in sapping the strength of metal upon which many valuable lives may depend. If metal be subject *pari passu* to vibration, its entire molecular structure may be rearranged, culminating in the disappearance of the fibrous character, and in its place the establishment of the crystalline structure characteristic of cast iron and the corresponding reduction of tensile strength. In calculating the effect of time and work in a metallic bar exposed to the effects producing vibration, both of the influences described should always be taken into account.

SPECIAL CAUSES FOR CORROSION

Other causes besides the chemical action of oxygen, water and acids may result in the corrosion of metals. For example, if iron and steel of different densities are brought into contact with each other, the less dense of the two is more liable to rust than the other.

Metals of electrical polarity opposite to those of iron and steel either reduce or accelerate the process of rusting or oxidation. For instance, metals that are electrically positive in relation to iron and steel preserve the latter more or less, and at their own expense. Zinc being positive in relation to iron and steel, the latter metals gain by contact with zinc, which suffers in like proportion. On the other hand, lead is negative in polarity relationship to iron and steel, and the oxidation of the latter is accelerated by contact. The same effect also applies to copper, brass, and more especially to gun-metal, which should never be brought into contact with iron or steel when exposed to an oxidizing environment, except under strict and sustained supervision.

If any one requires ocular proof of the effect of negative polarity, let him examine some old iron railings embedded in

lead, and he will find striking evidence of its existence in the attenuated character of the iron near the point of contact with the lead.

The Importance of Preservatives

It is now some fifty years since the completion of many of the metallic structures associated with the building of our railroads, and although, fortunately, the margin of safety adopted by the old school of engineers was high, it behooves the supervisors of our oldest railway structures to keep a vigilant watch over the metallic structures under their care, and which were built in the early days of the railway era.

The importance of preserving iron and steel from the strenuous efforts of oxygen and other agents, to restore them to their native condition of iron oxide or carbonate in which they are found, has been recognized by engineers and chemists ever since the beginning of the iron and steel age. It is particularly important that these metals should be adequately protected when employed in the construction of modern habitable structures, in which the metal framework forms the weight-bearing anatomy of the structure which may be the every-day habitat of hundreds of human beings.

That most building stones and bricks, as also terra-cotta, are not impervious to the flow of air and the penetration of moisture is well known, thanks to the classic researches of Pettenkofer and others. Therefore, it is only to be expected that unprotected steel columns, or beams embedded in brickwork, masonry, or terra-cotta, will suffer from the action of rust, more particularly when located in the basement and foundations of a building; hence the necessity for really efficient protective material becomes perfectly clear.

Cement and Cement Concrete as Efficient Preservatives

During the writer's examination of the steel-frame system of building construction in the United States, he inquired into the methods in use for preserving from oxidation the iron and steel employed in buildings. He learned that a covering of high-class Portland cement had proved an excellent preservative for iron and steel employed in the most trying situations. It had been found that the expansion and contraction of the

metal, owing to temperature variations, had synchronized with the expansion and contraction of the Portland cement, and that the removal of steel columns and beams after some years of service had shown that the coating of Portland cement had effectively preserved the metal from any appreciable oxidation or rusting effects.

Further demonstration of the preservative qualities of Portland cement is furnished by instances cited by various speakers, in a discussion on the preservation of materials, at a meeting of the American Society of Civil Engineers. The following facts are abstracted from the record of the discussion:

Mr. Rudolph P. Miller stated that, on the demolition of a modern steel skeleton building four years old, in New York City, the floor beams and girders, encased in cinder concrete, were found to be remarkably free from rust. Where there was any, it was in very small patches, more generally on the rivet heads, and it was probably there before the floor arches were placed.

Mr. George Hill, while admitting his interest in a paint business, expressed his conviction that steel which had been properly embedded in concrete remained absolutely unimpaired and perfect in its condition. He mentioned a series of experiments made by him for the representatives of the Melan system of reinforced concrete, in which steel bars were embedded in stone concrete. After exposure to the weather for from sixty to ninety days, wherever the concrete had been in contact with the steel, no rust showed at all. The steel was not painted, and showed bright; but wherever there were voids in the concrete, due to the use of rather dry cement with a stone aggregate, rust had set in.

In the same volume of the proceedings it is recorded that Mr. George W. Dickie, of the Union Iron Works, San Francisco, had used Portland cement for many years, with very satisfactory results, for the protection of iron and steel from corrosion. As an example it was stated that, while recently repairing the iron hull of a ship, Mr. Dickie had occasion to remove a portion of the cement floor which had been laid some forty years before, and the iron beneath the cement lining was then found to be absolutely free from rust. The fact that the cement was exposed to the most active kind of corrosion — that

caused by sea water — makes this experience a very strong argument in favor of Portland cement as a preservative of steel.

Turning now to experimental testimony, we may refer to the conclusions drawn by Professor Norton from his extensive series of investigations extending from 1901 to 1904. These researches demonstrate conclusively that neat Portland cement, even in thin layers, is an effective preventive of rust, and that cement concrete is equally effective if without voids or cracks and imperfect contact with the metal, but that it is of the utmost importance that the metal should be perfectly clean when bedded in concrete.

The absolute necessity for preventing the presence of voids near the metal was clearly established by Professor Norton, and is also indicated by the experience of Mr. Hill, stated before the American Society of Civil Engineers.

This is a point that should always be borne in mind, and another is that the cement used must be of really good quality. If these precautions are neglected, there will certainly be risk of corrosion. On the other hand, if Portland cement grout or concrete of approved quality be properly applied, there is not the slightest reason for fearing the corrosion of the iron or steel embedded in or covered by the material.

It is very important that the absolute safeguard offered by Portland cement should be universally recognized, especially in view of the recent injudicious repetition of rumors to the contrary.

The chemical reactions underlying the setting of Portland cement may to some extent explain its preservative influence. Any ordinary moisture present on the metal owing to the application of the cement will be absorbed in the setting process, so that one active element of oxidation will be removed. As the alkaline character of the cement serves to neutralize any acid, another destructive agency is counteracted. Further, as Portland cement is practically impervious to the penetration of air, oxygen cannot gain access to the metal to establish and maintain the process of corrosion.

"THE EARLY USE OF IRON"*

By BENNETT H. BROUGH

I N accepting the invitation with which I have been honored by the Council, to give a lecture to the West of Scotland Iron and Steel Institute, I feel that an apology is needed for having chosen a literary and antiquarian subject, that is inconsistent with the essentially practical nature of these meetings, and possibly with the very objects of the Society. At the same time, I think that many of the members will be willing to devote an hour to inquiring into the obsolete practices of their earliest predecessors, and to casting a glance backwards to the beginnfngs of the great industry with which they are all so intimately connected. The subject of the early use of iron has already been ably dealt with in papers read before the Philosophical Society of Glasgow, by St. John Vincent Day in 1871, and by Prof. A. Humboldt Sexton in 1900. Since the publication of these papers, however, much fresh light has been thrown on the subject by numerous archeological and literary researches. I propose, therefore, to give a brief summary of the results of these researches, and to set forth, as fully as possible in the time available, the existing knowledge of the metallurgy of iron and steel prior to the introduction of the blast furnace.

The date of the discovery of iron has long been a matter of controversy, and it is generally believed that the iron first used

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* Lecture delivered before the West of Scotland Iron and Steel Institute.

by man was of meteoric origin. In support of this view Mr. Otto Vogel has given quotations from the earliest Finnish poem; and Sir Henry Bessemer in 1895 adduced evidence to show that the tools used in the construction of the Pyramids must have been made of a meteoric nickel-alloy iron. The theory is, however, open to considerable doubt, in view of the difficulty of working meteoric iron. Indeed, many authorities have denied that meteoric iron is malleable. The hypothesis is, nevertheless, an attractive one. Blocks of meteoric iron, though not very numerous, have been found in all parts of the world. The British Museum collection, which includes specimens of nearly all the meteoric irons known, numbers 229, one of which fell in Great Britain, at Rowton, Shropshire, on April 20, 1876. The most remarkable of the larger masses was found in West Greenland, whence it was transported in 1894 by Capt. R. E. Peary to the American Museum of Natural History in New York. It is of very irregular shape, 11 feet long, 7½ feet wide and 6 feet thick, and weighs nearly 50 tons. The knowledge that iron and stones from time to time fell from heaven is very old. The meteorite still revered by the Moslems as one of their holiest relics, of which the history goes back far beyond the seventh century, is the oldest preserved. A fall mentioned in old Chinese manuscripts happened about 644 B.C. The oldest undoubted meteorite still preserved was seen to fall on November 16, 1492, at Ensisheim, in Alsace, where it was long suspended by a chain in the parish church, and is now kept in the town hall. The ancient Greeks and Romans supposed the stars to be the home of the gods. Falling stones signified the descent of a god, or the sending of its image to earth. The envoys were received with divine honors. A meteorite which recently fell in India was decked with flowers, daily anointed with clarified butter, and subjected to ceremonial worship. From 400 B.C. to 300 A.D. coins were struck in honor of such divinities. As a rule, the images were naturalistic in olden times, and became humanlike afterwards. Among the meteorites in whose honor coins were struck were the Omphalos of Delphi, a black stone given to Uranos instead of the new-born Zeus, the stone of Astarte which fell as a star from heaven and was worshiped at Sidon, represented on a coin of the Emperor Elagabalus lying on a car, and the conical stone of Aphrodite Urania. The rarity of meteoric falls is opposed to the theory that meteoric iron was the material used

by prehistoric man; and although some meteoric iron is malleable and there are undoubted cases in which it has been successfully forged, the difficulty of obtaining tools suitable for cutting a meteorite makes it probable that this material was used only in exceptional cases and that the first discovery of iron was due to the accidental melting of a rich iron oxide with charcoal.

The period of the first use of iron in ancient Egypt has been warmly discussed. Some contend for its use in mythological times, while others would bring it as late as 600 B.C., and, disregarding all evidence of the discovery of iron remains, insist that stone, copper and bronze tools were used exclusively up to that date, even in the building of the Pyramids. These wonders of the world, the graves of Egyptian kings, were built three thousand years before Christ. Herodotus tells of the building of the Great Pyramid, stating that 100,000 men were employed for twenty years, and he expresses wonder at the amount that must have been spent on their board and clothing and " on the iron with which they worked." The accuracy of the statements of Herodotus is borne out by the present condition of the Great Pyramid, which is built of granite blocks from the Upper Nile, lined with slabs of nummulitic limestone from Arabia. The magnificent temple at Thebes and the obelisks of a later period afford striking evidence of the technical skill, mathematical knowledge and excellent tools possessed by the ancient Egyptians. The evidence of ancient Egyptian metallurgy and mining are not of less importance. Gold was, of course, the metal most prized. There is preserved in the museum at Turin a map drawn fourteen hundred years before the Christian era, showing the situation of some ancient gold mines — undoubtedly the oldest topographical plan in existence. Diodorus describes how these mines were worked by slaves, and gives a harrowing picture of the hardships they suffered in these ancient Egyptian penal settlements. That iron was known to the Egyptians, even in the earliest times, is evident from their conspicuous metallurgical knowledge and from the facts that the working of granite and porphyry is scarcely conceivable without steel tools, that the oldest tombs have inscriptions referring to iron, and that sources of supply of manganiferous iron ore were found by Professor Bauerman in upper Egypt. All possible doubt has been removed by remarkable archeological discoveries. An iron sickle, found by Belzoni under the feet of one of the sphinxes at Karnak,

is deposited in the British Museum and proves that the smith's art was practiced at about 600 B.C. In 1837 a fragment of a wrought-iron tool was found in blasting operations in the Great Pyramid. This piece of iron, nearly five thousand years old, is also preserved in the British Museum. Analysis showed it to contain a small proportion of nickel, but as it also contained combined carbon, it was not of meteoric origin. In the British Museum there is also exhibited a lump of what is now iron rust, which was found wrapped up in a fabric with a mirror and tools of copper dating back to 3300 to 3100 B.C. Much stress is laid by supporters of the theory of the primitive use of meteoric iron on the interpretation of the Egyptian word for iron, " benipe," as " metal from the sky." In view of the fact that in Egyptian mural paintings blue is the conventional color for iron, one cannot help suggesting that the word might be translated as " metal of sky-blue." Much of the metal used in Egypt was imported as finished material from Ethiopia and later from Phœnician merchants. Indeed, it is probable that Ethiopia was the earliest center of iron manufacture. The illustrations preserved of Egyptian iron manufacture show that the process was precisely the same as that still obtaining among Ethiopian races. On a stone, preserved at Florence, a negro slave is depicted working bellows from which the blast is conveyed by a bamboo pipe to a shallow pit in which the iron is smelted. In a second illustration is shown the forging of the iron by hammering it with a rounded stone on a stone anvil with wooden base. It is clearly proved by pictures on Egyptian tombs that bellows were in use in the fifteenth century before Christ. This shows a distinct advance over the primitive method of smelting on a windy hillside, and it is curious to note that even at the present day furnaces with a natural air draft are used for lead smelting in Bolivia. An idea of the relative value of iron in the fifteenth century before Christ is given by the story told by Herodotus (ii, chap. 135) of the beautiful Rhodopis, who, having amassed great wealth in Egypt, wished to leave a memorial of herself in Greece. She therefore determined to have something made, the like of which was not to be found in any temple, and to offer it at the shrine at Delphi. So she set apart a tenth of her possessions and purchased with the money a quantity of iron spits, such as are fit for roasting an ox whole, which she presented to the oracle. Rhodopis lived in Egypt in the reign of Amasis (570 to 526 B.C.).

Turning to the eastern neighbors of the Egyptians, the Semitic peoples inhabiting the country between the Mediterranean and Persia, we find that iron was known to the Chaldeans from the earliest times. The action of rust has, however, prevented discoveries of much in the way of iron in the ruins of Babylon. Only iron rings and bracelets have been found. A cuneiform inscription in the British Museum is interpreted to mean, " With an iron sword I slew another lion." In 1867 the discovery was made in the ruins of the palace of Khorsabad of a store of merchant iron perforated with holes to facilitate transport. It is evident that the kings of Assyria stored up in their treasure houses masses of iron for building and war. The Assyrians were acquainted with steel, but, like all other ancient peoples, had no knowledge of cast iron.

In Syria the fame of the swords sold in the market at Damascus dates back to the earliest times. In the time of Abraham, Damascus was an important commercial center. At a later date the Roman Emperor Diocletian had a sword factory there for his army, and even in the time of the Crusades the swords made of a combination of steel and wrought iron, polished and lightly etched, were prized throughout Europe. Iron was worked with skill, and long before Moses came to Canaan there was a high degree of civilization in this promised land, that was inherited by the Children of Israel and the Phœnicians. The latter traded throughout the world in the rich products of Palestine, and possessed greater skill in metallurgy than the Israelites, as is well shown in the Biblical account of the metal work of King Solomon's temple. Numerous Scriptural references show, however, that the Israelites had an intimate knowledge of the working of iron and steel. Iron was known in the days of Job (xxviii, 2). Moses mentions " Tubal-Cain, an instructor of every artificer in brass and iron " (Gen. iv, 22), and compares Egypt to " the iron furnace " (Deut. iv, 20). Og, king of Bashan, who lived about 1450 B.C., had a bedstead of iron (Deut. iii, 11). Joshua (x, 20), it will be remembered, besieged Lachish, a city of the Amorites, which then became an important stronghold of the Israelites. It was finally deserted about 400 B.C. The mound has recently been explored by Petrie, who found in the remains of the Amorite city (probably 1500 B.C.) large weapons of pure copper; above this, dating 1250 to 800 B.C., appear bronze tools, which gradually become scarcer, until at the top of the mound there is little else than iron.

To our forefathers, the Aryans in India, iron was known at a very early date, and used for weapons and tools. Iron ore was abundant; and the lack of copper makes it probable that the iron age in India was not preceded by a bronze age. Indian iron and steel, even in very ancient times, were celebrated throughout the world; and the knowledge of metallurgy possessed must have been considerable. Evidence of this is afforded by the iron pillar at Delphi, which is 50 feet high and 16 inches in diameter and appears to have been made of 50-pound blooms welded together. It dates back to at least 912 years B.C. The primitive processes of iron and steel manufacture in India are described in detail by Dr. Percy, and in 1905 Dr. A. K. Coomaraswamy described the processes still surviving in Ceylon. The furnace is sheltered beneath the thatched roof of a shed open on all sides. The essential parts of the furnace are the well or furnace proper, a wall of sticks and mud to protect the bellows-blower from the heat of the fire and the bellows behind the wall. The bellows consist of two hollowed logs of wood embedded in the ground, with a piece of deerskin stretched over each, with a small hole near the center to which a cord is attached. This is fastened above to a springy stick, the lower end of which is fixed in the ground. A small pipe conveys the blast into the furnace. The bellows-blower places a foot on each skin, and pressing his feet down in turn drives a continuous blast into the furnace, his foot acting as a valve, and the skin being pulled up by the tension of the cord. There is a bar for the blower to grip, and a strap to serve as a seat. The ore, limonite, is roasted previous to charging. The furnace is filled with layers of roasted ore and charcoal. When the bloom is ready it is taken out in long tongs made of green-wood sticks. Steel is sometimes made by a somewhat more delicate process. The wall and bellows are similar to those used for iron smelting, but the hearth is merely a semicircular depression filled with charcoal, into which the blast is conducted. Around this actual hearth is a low clay wall. The steel is made in clay tubes, each 8 inches long and 2 inches in diameter, the clay being 14 inches thick. Into it is placed a piece of iron and some chips of wood, the proportion being $12\frac{1}{2}$ ounces of iron to 5 ounces of wood. The tube is then closed with a lid of clay, with small holes pierced for the escape of gas. The tubes are imbedded in the charcoal and a fire started. Very soon the gases from the wood burn off,

the blowing being stopped in the meantime. Then the blast is kept up continuously, while the tubes are turned about. When the steel is likely to be ready, a hole is opened in the front part of the hearth so that the blast goes right through the furnace, and the tubes are lifted up one by one in long iron tongs and shaken to ascertain if the steel is liquid. The tubes are then allowed to cool and subsequently broken open and the bar of steel removed.

The Indian methods of iron and steel manufacture were brought to European knowledge in the Middle Ages by gypsies, who appear to have come originally from India. In Hungary at the present day they carry on iron smelting and forging.

Another classic land for metallurgy is Armenia, the land of the Chalybes, whence the kings of Assyria drew tribute of iron. The Chalybes were regarded by the Greeks as the inventors of steel, and the name of the people was applied to steel.

Recent researches on early Chinese history have brought to light references to the use of iron and steel dating back to 2357 B.C. Marco Polo, the Venetian, in the thirteenth century refers to the use of coal in China, but he gives no particulars of Chinese iron manufacture.

Japan appears to have been colonized from China about 1240 B.C. Japanese copper has been famed from the earliest times and iron ore has long been mined. The mining operations, until the introduction of Western methods, were of a primitive character, but considerable depths appear to have been reached. Swedenborg, writing in 1734 (" De Ferro," p. 194), states that the Japanese made their steel by forging iron into bars and burying these bars for eight or ten years in marshy ground, the unrusted portion then being steel. This process is described by several classic writers as being used elsewhere. It would be interesting to ascertain if there is any basis of truth in this description of the method of dealing with the mixture of wrought iron and steel produced by the imperfect smelting process used. The high quality of Japanese swords is far-famed, and the method of manufacture which enables them to be made still survives. The ore used was chiefly magnetic sand, which was obtained as far back as the year 1264. The ore was concentrated to about 60 per cent of iron. The blast, which was worked by hand, was intermittent. The furnaces were rectangular, 10 feet long and from 4 to 6 feet high. The product is in part cast iron and in

part a lump of malleable iron and steel. The antiquity of the Japanese iron industry has been proved by Professor Gowland, who has made a thorough study of Japanese metallurgy. In his investigations of Japanese dolmens, or stone burial chambers, dating from the second century B.C. to 700 A.D., he found iron swords, arrow heads, spear heads and horse furniture. In most countries the remains found in dolmens are of stone or bronze, but in Japan all belong to the iron age.

In Africa the metallurgical operations of the negro peoples, who are regarded as the original inhabitants, present special interest. There was in Africa no bronze age, and the development of iron metallurgy was spontaneous. In Abyssinia the smith is looked upon with mingled dread and superstition. He is supposed to be able to communicate his magic power to others and to turn himself into a hyena at will. The primitive African methods of iron and steel making in furnaces worked by natural draft have frequently been described. The most recent and most detailed account was that given by Mr. C. V. Bellamy in a paper read at the New York meeting of the Iron and Steel Institute in 1904, in which he described the process carried out in West Africa in the hinterland of the British colony of Lagos. The ore used is a silicious hematite occurring in shale. It is roasted and then pulverized in a wooden mortar. The pounded ore is then washed by women. A hole is dug in the ground about 2 feet deep and filled with water. In this a woman stands and washes the ore in a tray about 18 inches in diameter. It is then subjected to a further and more careful washing by a second woman, seated on the ground near by. The ore is then conveyed to the furnace in a smelting shed, of which there are eleven in the village. Each shed is about 25 feet long and 16 feet wide, with a doorway at each end. The walls are built of clay and are from 4 to 6 feet high. They are not carried up to the roof, but a space is left all around for light and ventilation. From the ground to the ridge of the roof the height is 25 feet. The furnace is in the center of the shed. It is built of clay and occupies a circular space 7 feet in diameter. Its height is 3 feet 9 inches. Opposite one of the doorways, a depression in the floor gives access to the furnace. The dome of the furnace is bound round by a rope of twisted vines. In the center of the bottom of the furnace is an aperture 3 inches in diameter, which communicates with a short tunnel below the floor of the shed, to which access is ob-

tained by a pit inside the shed. The shed also contains a small kiln for firing the earthenware tuyères, and an ore-bin, both being made of clay. The process of smelting occupies thirty-six hours, draft being supplied by nine pairs of earthenware pipes. These are only rudely shaped by hand around a stick and but partly baked. The average diameter of each pipe is 1.4 inches. Selected slag from each successive smelting is used as flux. It is run off by opening the orifice in the bottom of the furnace. For removing the bloom, the clay seals over the six apertures are broken up, the earthenware pipes removed and thrown aside and the doorway of the furnace opened. The contents of live charcoal are raked out and the 70-pound bloom removed in a red-hot state by a loop of green creeper. Subsequently it is broken up, with the aid of a stone, into convenient sizes and sold to smiths. The metal produced in this way is a natural forged steel, which, by reheating by the native smith, is brought down to a tool steel with ·1 per cent of carbon. It is difficult to realize that in a part of the world which is within twenty days of the great European manufacturing centers, the smelting methods practiced by the earliest ironworkers can still be seen in operation.

From western Asia and Egypt civilization came to Greece. Cyprus and Crete were the oldest Phœnician settlements, and these islands were the starting-points of Greek metallurgy. Hephæstus (Vulcan) was, according to tradition, the first to work in iron, and he is often represented forging the bolts of Zeus. References to "iron wrought with much toil" are frequent in the poems of Homer (880 B.C.). Hardening steel by quenching is adopted as a simile in the description of the blinding of Polyphemus (Odyssey ix, 391). Iron is referred to as a treasure, and a bloom of iron is the valuable prize offered by Achilles at games (*Ibid.*, xxiii, 826). Evidently a considerable degree of skill in working iron had been attained. But the heroes used copper or bronze, metallurgy and mining being still in Phœnician hands. The silver mines at Laurium, in Attica, were even then being worked with slave labor by the Phœnicians. An iron knife and an iron dagger were found by Schliemann in his excavations on the site of Troy. The oldest mines worked by the Greeks were the iron mines of Eubœa (Chalcis). From the earliest times the Spartans wore iron rings and used iron bars as currency, a practice that was not abandoned until 320 B.C.

Little is known of the methods of iron smelting used by the Greeks, as the metallurgical treatises written by Aristotle (384–322 B.C.) and his pupil Theophrastus (372–287 B.C.) have not been preserved. Somewhat obscure passages in the latter author's book on stones indicate that the Greeks were acquainted with the coking of coal, with the use of coal in iron smelting and with the tinning of iron. Aristarchus, however, in the second century before Christ says definitely that iron cannot be melted or cast. Although written records are sparse, the numerous sculptures and painted vases that have been preserved throw some light on the metallurgical methods of the ancient Greeks.

Passing on to Italy and the Romans, we find that mining and metallurgy were early practiced by the Etruscans. Copper and iron were mined in their own land, notably in Elba and in the Tuscan hills. Diodorus Siculus (a contemporary of Julius Cæsar) and Aristotle refer to the great antiquity of the Elba iron mines, which were originally started to work a copper vein. Among the Romans iron appears to have been used earlier than bronze. One of the oldest customs of the Romans was to wear iron rings on the right hand. Even the statues of the kings Numa Pompilius and Servius Tullius bear these rings. Pliny (23–79 A.D.) refers at length to the custom (xxxiii, 4, 5, 6). In the early days of Rome there was little scope for metallurgy, but with the Punic wars, culminating in the sack of Carthage, the foundation of the world's empire of Rome began. All the mines in Europe gradually fell into the hands of the Roman state and were worked by slaves. The details of metallurgical practice supplied us by Latin authors are as sparse as those of the Greeks. Most information is supplied by Pliny's " Natural History." Iron he describes as the best and at the same time the worst help to man, and, as the metal of foolhardiness, better suited than gold for war and murder. He gives interesting details of the manufacture of iron. He notes that the differences in iron are remarkable, and that on smelting the ore the iron becomes liquid like water (" *mirumque cum excoquatur vena aquae modo liquari ferrum* "). He describes the Bilbao iron-ore deposits and refers to the medicinal value of iron. Next to the Elba iron, the Styrian (Noricum) iron is mentioned by him as the most celebrated at this epoch.

The wonderful mechanical skill of the Greeks and Romans is well shown in the works of Vitruvius (46 B.C.) and of Hero

of Alexandria (285-222 B.C.). The water level for Vitruvius is
a surveying instrument of great accuracy, and the automatic
coin-in-the-slot machine and the toy steam turbine of Hero of
Alexandria suggest how rapid might have been technical progress
had not thirst for conquest on the one hand, and envy and
revenge on the other, given rise to wars and massacres that
caused the inventions and progress made to be swept away and
ignored for five hundred years.

It is difficult to realize the mass of artistic treasures that were
destroyed when the Asiatic barbarian Huns burst across the
Volga in the year 374 A.D. Manufactories were also destroyed.
The iron trade suffered, but iron weapons were needed and the
primitive furnaces in the forests remained untouched. There
are no written records of these furnaces of prehistoric time,
and all we have to guide us are the archeological discoveries
which year by year add to our knowledge of the metallurgical
practice of the ancient inhabitants of Europe.

Numerous iron objects of prehistoric date have been found
in northern Europe, where iron was undoubtedly the first metal
to be used. Iron weapons, too, have been found in the remains
of pile dwellings in Switzerland. In that country the Bernese
Jura abounds in remains of prehistoric iron smelting, which
have been carefully investigated by Quiquerez, a scientifically
trained mining official. The furnaces were in dense forests, in
order to obtain an easy supply of wood. The workmen dwelt
in caves, and charcoal was burned in piles. The furnaces were
all similar, differing merely in size. On the natural ground,
with no foundation, the hearth of firebrick was laid. Lumps
of the same material formed the walls, which were supported
externally by undressed stones filled in with earth. Two
inches above the hearth a channel was left open, which had the
entire width of the hearth, was arched over and widened out
at the exterior. It was made of fireclay, the aperture consisting
of several large stones which were covered with a stone slab.
The shaft of the furnace was cylindrical and inclined towards
the top, so that charcoal and ore would pass down on one side,
leaving the other free for the air current. The shaft was 8 feet
high, and the top was surrounded by a circle of stones. The
furnaces were charged from above. The air entered at the base,
no bellows being used. The opening at the base thus served
as a tuyère, slag hole and discharging hole for the blooms,

which were from 30 to 50 pounds in weight. At several of these prehistoric furnaces flint implements were found, showing that the Swiss iron industry dates back to the stone age, before bronze was introduced by foreign merchants.

In 1905 Mr. G. Arth and Mr. P. Lejeune made an investigation of a prehistoric mass of metal found near Nancy at a depth of 15 feet below the surface. The mass is 660 pounds in weight and was accompanied by fragments of charcoal and slag. It appears to have been the base of an ancient hearth in which the metal had been subjected to repeated and prolonged heating. The metal contains, in addition to iron, 1.21 per cent of combined carbon, 0.04 per cent of graphite, 1.67 per cent of silicon, 0.026 per cent of sulphur, 0.013 per cent of phosphorus and 0.18 per cent of manganese. It is, therefore, a steel containing a higher percentage of silicon than that now usual. The slag contains 63.9 per cent of silica. The microscopic examination showed that it belongs to Guillet's first group of silicon steels — pearlite steels consisting of a solid solution of iron silicide in iron. The low percentage of phosphorus indicates that the ore must have been obtained from the abandoned thick bed of ore, and not from the phosphoric " minette " now mined in the district.

The prehistoric cemetery at the salt-mining town of Hall-stadt, in upper Austria, has proved the most remarkable source of supply of bronze and iron implements. The number of graves opened was 993 and the number of objects found was 6,084. Nowhere else has such a mixture of bronze and iron objects been found. Salt has been mined at Hallstadt since the earliest times, and modern mining operations have encountered the old workings of the prehistoric miners, and the objects found render it evident that salt mining was here carried on 900 B.C. The prehistoric mines reached depths of as much as 200 yards. Wedges of serpentine, tools of copper and bronze, numerous wooden articles and remains of skin clothing have been found in good preservation. Specially noteworthy are two sacks for the transport of salt, preserved in the Vienna Museum. They are 30 inches long and made of raw oxhide. For carrying the sacks there is a leather strap that passed over one shoulder, and a wooden handle 15 inches long fastened by two straps to the upper part of the sack. With this handle the sack could be securely held when full, and on releasing

the handle, the contents of the sack could be tipped backwards. A loop was provided for hanging up the sack. The finds of the Hallstadt cemetery have been classed by Montelius according to the swords discovered. The first period (850 to 600 B.C.) is characterized by bronze swords, and the second (600 to 400 B.C.) by iron swords. There are also transition bronze swords with iron blades.

The civilization of La Tène presents several important contrasts to that of the salt-mining community of the Austrian Tyrol. The site which has furnished a name for the second half of the early iron age (400 to 1 B.C.) has yielded an enormous number of antiquities. It lies in a small bay at the northern end of the lake of Neuchatel, and the ancient settlement was built on piles. Among the relics from this station, exhibited in the British Museum, may be mentioned an iron brooch, an elaborated form of the modern safety-pin. The ring or collar which kept the end in position is characteristic of the locality. The La Tène swords also have characteristic scabbards; and some remarkable short swords of this period, with bronze handles of the anthropoid type, are shown in the British Museum. They are named from the human head in the angle of the pommel. The handles are not of solid bronze, but have an iron core. In Spain iron swords of yataghan type are a peculiarity of the La Tène period. In East Yorkshire Mr. J. R. Mortimer described, in 1905, the discovery of a sword of this period of a kind not previously found in Britain, and believes that it may date from 100 B.C.

Dr. Hjalmar Braune in 1905 published an analysis of a prehistoric iron object found at Castaneda, in Switzerland. It was the handle of a thin bronze water-jug, the iron having been protected by the bronze from rust. The iron remaining gave on analysis: Carbon, 0.14–0.18; silicon, 0.005–0.08; sulphur, 0.012; phosphorus, 0.057; nitrogen, 0.008. It contained no manganese, cobalt, or nickel, and was evidently made from ore free from phosphorus, sulphur and manganese — in all probability from Elba. This is borne out by the fact that bronze must have been made from a tin-bearing copper ore such as was produced at the Etruscan mines of Campiglia Marittima, on the mainland opposite Elba. An examination of a polished surface of the iron etched with dilute hydrochloric acid shows that the metal consists chiefly of a very soft, almost pure, iron,

with harder portions where carbon has been taken up. The oxidation has followed the lines of admixed slag. It is evident that the iron has never been in a molten condition.

In Britain development was slow. External influences did not change so rapidly as on the Continent, and consequently the Britons adhered longer to their flint weapons and implements, in the manufacture of which they attained remarkable skill. Indeed, the old flint mines at Brandon, in Somerset, are still worked for supplying gun flints to savage tribes. In Ireland the use of stone implements was continued well into historic times. Nevertheless, Britain possessed in tin a metal that was sought after by all the world. The tin trade was monopolized by Phœnician merchants until 300 B.C.. Then came the fall of Phœnicia and the Phœnician colonies fell into the hands of the Greeks. When Cæsar invaded Britain, in 54 B.C., he found the inhabitants, owing to Greek influence, not entirely uncivilized and carrying on an active tin trade with Gaul. Iron manufacture was carried on, and Cæsar states that for currency copper or gold coins, or iron bars of given weight, were used ("*Utuntur aut aere, aut nummo aureo, aut taleis ferreis ad certum pondus examinatis pro nummo*"). This passage has suffered much at the hands of transcribers, and many authors, including Dr. Percy, have accepted the reading "annulis," and have accounted for the total disappearance of the iron-ring coinage by oxidation. A fresh ray of light has been thrown on the matter by Mr. Reginald A. Smith, of the British Museum, who, in a paper read before the Society of Antiquaries in 1905, described a remarkable series of iron bars that were undoubtedly the money described by Cæsar. They roughly resemble swords with a rude handle in a square end, averaging 2 feet $7\frac{1}{2}$ inches in length, and have often been found secreted in a manner suggestive of hoards of coins. Several specimens are preserved in the British Museum. There are three series, all of similar form. In the first the weight is approximately 4,770 grains, in the second the weight is double (9,540 grains) and in the third the weight is quadruple (19,080 grains). A convincing proof of Mr. Smith's contention is afforded by the fact that there is preserved in the Cardiff Museum a bronze weight of 4,770 grains found in a hoard of late Celtic bronzes at Neath. It is of a common Roman form, cheese-shaped, with " I " cut on the top. A similar weight, but made of basalt (4,767 grains),

is in the museum at Mayence. As these British currency bars do not date earlier than 400 B.C., their use must have been due to Greek influence. We know that the Spartan money took the form of iron bars; and even at the present day in Central Africa iron bars, spearheads and other forms with uncomfortable spikes, are used as currency.

Mr. Smith's theory appears to me to be borne out by the weights of 26 spindle-shaped iron blocks found in 1866 at Monzenheim, and now for the most part preserved in the museum at Mayence. These blocks are on an average sixteen times as heavy as Mr. Smith's unit weight of 4,770 grains or 309.74 grams. Eight of them, including the heaviest and the lightest, gave the following weights: 4,000, 4,050, 5,000, 5,000, 5,120, 5,470 and 5,700 grams. Apparently they are blooms made in the forest forges, of a weight suitable for currency, there being no decimal system of weights in those days, when the advantages of continual bisection were fully appreciated. The form was convenient for the smith, as he held the bloom at one end and forged one half. The blooms would be convenient to transport, as the smith could carry them as miners often do their drills, with a strap on his back and breast, horizontally, leaving his arms free. The purchaser, too, could easily try the pointed end in his forge, to ascertain the quality of the iron. Analyses of two of the British currency bars (A and B), made by Prof. W. Gowland, and of a Monzenheim bloom (C) by Dr. Ludwig Beck, gave the following results:

	A	B	C
Carbon	trace	0.08	0.43
Silicon	0.09	0.02	0.36
Phosphorus	0.69	0.35	0.24
Manganese	nil	nil	0.48
Nickel	0.23	nil	—
Sulphur	—	—	0.25

Bar A, when examined microscopically, showed no slag patches and may have been an exceptional case of the use of meteoric iron, although it contains less than the 6 to 10 per cent of nickel usual in such metal. Bar B appears to have been produced by the direct reduction of Forest of Dean ore. The bloom C is a soft iron containing a considerable proportion of impurities.

The shape of the currency bars, one cannot help thinking,

must have been chosen so as to enable the owner, if necessary, to convert his money into a sword. The spindle-shaped blooms, however, were of a form that was frequently adopted in early times. Even the iron blocks in the treasure-houses at Nineveh had a similar form, but the Assyrian blooms were all perforated, for convenience of transport, with a strap. It will be remembered, too, that in Sweden, the " Järnbäraland," or " mother-land of iron " as it was called in the seventh century, the Osmund blooms obtained in the peasant furnaces were broken into from 24 to 29 pieces each weighing a pound, and these Osmund pieces served as currency even in foreign countries from the beginning of the thirteenth century, and continued to do so until their export was forbidden by Gustavus Wasa. The copper-plate money to be seen at the museum at Falun, in Sweden, is a further example of the use of heavy masses of metal as currency. The largest, a 10-dollar plate, dated 1644, weighed no less than $43\frac{1}{2}$ pounds.

The Roman influence in Britain was considerable and lasting, but the subjection was not complete until the year 84. When the Emperor Hadrian came to Britain in 120, he founded an arms factory at Bath, using iron from the Forest of Dean, and the mines there were worked until the year 409. Indeed, the enormous heaps of slag left by the Romans furnished the chief supply to twenty furnaces for nearly three hundred years. Similar slag-heaps have been found in Sussex and elsewhere. From explorations made within the Roman fortifications at Wilderspool, near Warrington, Mr. Thomas May has been able to deduce the form of furnace used, and he published, in 1905, an interesting account of his remarkable discoveries. Association with Roman pottery and with a hundred coins dating from 27 B.C. to 337 A.D., shows that furnaces found are of the latest period of the Roman occupation, 410 A.D. The furnaces consisted essentially of a cavity with a wall and covering of clay, with holes in the base for admitting the draught and for withdrawing the metal. They were usually placed on sloping ground. The remains are of special interest, inasmuch as they show that coal was used with charcoal for smelting,— fragments of cannel coal having been found,— and that some of the iron was obtained in a molten state. Indeed, Mr. May considers that there is evidence in support of the view that an indirect method

of producing cast iron in one furnace and of converting it into malleable iron in another was practiced by the Romans at Warrington. Interesting as Mr. May's discoveries are, his interpretation of them is not convincing. There is no proof that either bellows or clay molds for casting were used. The plant appears to have consisted of a roasting kiln, a smelting furnace and a smith's forge. The fact that some coal was used may explain why some of the metal, like the minute specimen found, collected in a fluid state on the furnace bottom. The metal, as in the direct process carried out at Lagos, was essentially a natural steel, which, by reheating, was brought down to a malleable iron with a very low percentage of carbon. The process was somewhat similar to that described by Agricola, who makes no mention of cast iron. The passage translated by Mr. May, " From such ore, sometimes once, sometimes twice roasted, iron is *melted* suitable for being reheated in the smithy furnace," should read, " From such ore, once or twice roasted, iron is made, which is again made hot in the smith's forge and is flattened out under the hammer, which is lifted by a water-wheel and cut in pieces with the sharp iron." The analysis of the supposed cast iron, given by Mr. May, is so remarkable that it is to be regretted that no microscopical examination of the metal was undertaken. It might even be found that the $1\frac{1}{2}$-inch cube of metal described as cast iron was a furnace accretion composed of metal with unconsumed particles of charcoal, appearing in the analysis as graphitic carbon. Owing to roasting, the analysis of ancient irons presents great difficulties; and these are notably the case with cast iron. A cast-iron cannon ball, for example, recently discovered in making the Paris underground railway, under the site of the old Bastille, whilst retaining its original shape, was found to consist chiefly of iron oxide. Its specific gravity was 4.854 instead of 7.6; and under the microscope it was found that the pearlite, which in admixture with cementite usually constitutes ordinary white pig iron, was oxidized throughout, whilst the cementite had preserved its metallic state. An analysis of the cannon ball by Mr. A. Portlier gave 5.9 per cent of carbon, 0.25 per cent of silicon, 0.75 per cent of manganese, 2.9 per cent of moisture, 72.0 per cent of iron and 17.45 per cent of oxygen. The high percentage of carbon shows that some of the iron had

been expelled, the original carbon percentage in the pig having probably been below 4. It is interesting to compare these results with the analysis given by Mr. May of supposed Roman cast iron that had been subjected to oxidizing influences for fifteen hundred years. His figures are as follows: Iron, 94.08; combined carbon, 0.23; graphite, 3.0; silicon, 1.05; sulphur, 0.48; phosphorus, 0.75; and manganese, 0.40 per cent.

In the early Middle Ages, although little progress was made in iron smelting, great advances were made in the manipulation of iron and steel. The sword was the triumph of the smith's art, but the manufacture of defensive armor called for skill of no mean order. The value of iron was, however, fully recognized. Writing in 1260, Bartholomew, the English Franciscan, says: " Use of iron is more needful to men in many things than use of gold, though covetous men love more gold than iron. Without iron the commonalty be not sure against enemies; without dread of iron the common right is not governed; with iron innocent men are defended, and foolhardiness of wicked men is chastised with dread of iron. And well nigh no handiwork is wrought without iron; no field is earned without iron, neither tilling craft used, nor building builded without iron."

The invention of gunpowder, somewhere about 1310 to 1320, had a remarkable influence on iron manufacture, and it is interesting in tracing the history of ordnance, to see the advances in the iron industry occasioned by the increasing demands of the artillerist. Although the first cannon of Berthold Schwarz were cast in bronze, it was not long before far more durable cannon were forged of iron bars hooped together, and the huge cannon such as Mons Meg (1455) at Edinburgh and La Dulle Griète at Ghent are remarkable examples of the skill in forging attained. The furnaces in which wrought iron was made at this epoch — the Catalan hearth, the Corsican furnace, the Osmund furnace and the German Stückofen — are fully described in the historical treatises of Beck (5 vols., Brunswick, 1884–1903) and of Swank (Philadelphia, 1892), as well as in the standard metallurgical treatises of Percy, Bauerman and others. From these furnaces, in which the metal was obtained in the malleable state in one operation, to the blast furnace, the transition was gradual. The basis of modern metallurgy was afforded by the discovery of cast iron and by

the employment of water wheels in the year 1323, for working the blast. The works were then removed from the forests to the river valleys. Iron cannon balls were cast by Ulrich Beham in Memmingen in 1388, but cast-iron cannon are not mentioned before the fifteenth century. In 1412 two cannon, each 45 pounds in weight, were cast for the town of Lille and in 1422 cast-iron cannon were in use in the Hussite wars. The explanation of the late use of iron for castings is undoubtedly to be found in the unsuitability of the white pig iron originally made. It was not until the height of the furnaces was increased that silicon could be reduced and gray pig obtained.

All the metallurgical operations of the ancients were entirely empirical. Nothing was known of the assaying of ores. Color and weight were the only indications of the quality of an iron ore. The idea of the transmutation of metals, which formed the aim of the chemical operations of the Middle Ages, did not go back to classic times. Geber, in the eighth century, was the first to recognize a metal as a fusible and malleable substance. He taught that all metals consist of sulphur and quicksilver in varying proportions. Alchemy did nothing to advance the iron industry, but there were besides the alchemists other philosophers who cared nothing for these things. Preëminent among these were Theophilus, the priest and monk, and Leonardo da Vinci, the artist. The former was a German who lived in the second half of the eleventh century. He was not only an author but also a skilled worker in metals, and his book contains, besides the usual superstitions of the age, many practical observations, and gives a good idea of the workshop practice of a medieval metallurgist. Leonardo da Vinci, who lived three hundred years later, was not only a great painter and sculptor but also an engineer and philosopher, with an astonishing knowledge of physics and mechanics. He developed the idea of the artesian well and constructed deep boring plant, pumps, water wheels, hydraulic presses, canals and locks. He made a steam cannon and had a dim idea of many other late inventions. His metallurgical knowledge was considerable. Among the many drawings left by him, one of a file-cutting machine is specially remarkable.

Georgius Agricola, who wrote the first systematic treatise on mining, living in Saxony, where no iron was worked, says but little about iron smelting. His illustrations show the in-

creased height of the furnace, but he makes no reference to melting or casting iron. The subject of iron founding is, however, noticed by Lazarus Ercker in his work on assaying, published in 1574.

With the discovery of cast iron and the introduction of the blast furnace, the first stage in the history of iron closes with the end of the fifteenth century. Epoch-making inventions and discoveries soon followed. The introduction of coal as fuel for smelting by Dud Dudley in 1618, the replacement of coal by coke, the building by James Watt of the first blowing engine at the Carron ironworks in 1760, of puddling by Henry Cort in 1784, of the hot blast by Neilson in 1828, of the Bessemer process in 1856, of open-hearth steel making in 1861 and of basic steel making in 1879, are a few of the great improvements that have led to the marvelous development of the iron trade in this and other countries, and have rendered it possible for the world to produce, as it is now doing, 45,000,000 tons of pig iron annually.

ABSTRACTS *

(From recent articles of interest to the Iron and Steel Metallurgist)

THE Works of the English McKenna Process Company. "Engineering," March 2, 1906. 2,000 w., illustrated. (To be continued.) — The McKenna process may be briefly defined as a method of making new rails from old ones, and, moreover, of effecting this change with the least expenditure of time and labor. Of the thousands of tons of old rails which are annually thrown out by the railway companies as being too badly worn for main line traffic, the great majority have to be cut up, re-melted, and again passed through the rolls before they can be put to any further use. A certain percentage, of course, are relaid for lighter traffic on branch lines or in contractors' yards, or are even made use of for certain structural purposes before they come to their inevitable end on the scrap heap; but the comparatively small amount of wear which is required to unfit a rail for important traffic makes it necessary to discard thousands of rails whose only fault is that the head has lost its standard shape. Besides worn rails, there are many which, though fresh from the rolls, are declined by the customer because of a slight variation from the specified dimensions, and these, also, if salable at all, have to be disposed of at reduced prices. It is the object of the McKenna process to deal with rails which, either from wear or from any other cause, are not of the standard size and shape, and to re-roll them to a slightly smaller

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* NOTE. The publishers will endeavor to supply upon request the full text of the articles here abstracted, together with all illustrations, plans, etc. The charge for this is indicated by the letter following the number of each abstract. — Thus "A" denotes 20 cents, "B" 40 cents, "C" 60 cents, "D" 80 cents, "E" $1.00, "F" $1.20, "G" $1.60, and "H" $2.00. Where there is no letter the price will be given upon request. In all cases the article furnished will be in the original language unless a translation is specifically desired, in which case an extra charge will be made depending upon the length and character of the text.

When ordering, both the number and name of the abstract should be mentioned.

standard size.   The process has been in operation in the United States for some eight or nine years, three works there being entirely devoted to the renovation of rails, and so successful was it that the English McKenna Process Company, Limited, was formed to exploit the system in this country.   The latter company is closely allied with the American McKenna Company, and has consequently had the benefit of the experience gained in America, in connection with the erection and operation of the works on this side.

The English McKenna Process Company, Limited, owns well-equipped and conveniently situated works at Seacombe, Birkenhead.   The works stand on an open site of 34 acres, and have excellent facilities for the transport of their raw and finished material both by rail and water. . **No. 483. B.**

Roll-Turning: Its Scope and Possibilities. By W. S. Standiford.   " The Mechanical World," March 9, 1906.   3,000 w. — A description of the tools and methods required for roll turning. **No. 484. A.**

On the Formation of Blowholes in Steel Ingots (Ueber die Bildung von Hohlräumen in Stahlblocken).   By J. Riemer. " Stahl und Eisen," February 15, 1906.   3,000 w., illustrated. — The author discusses the causes of blowholes and pipes in steel ingots and the resulting defects in finished products. **No. 485. C.**

Determinations of Hardness by the Brinell Method (Determinations de Dureté d'après la Méthode Brinell).   " Baumaterialienkunde," January 1, 1906.   3,000 w., illustrated. — A short description of the well-known Brinell method or " ball test," including a description of a special testing machine to conduct the test. **No. 486.   B.**

Electric Driving of Reversing Rolling Mill Trains (Elektrischer Antrieb von Reversierwalzenstrassen).   F. Weideneder. " Stahl und Eisen," February 1, 1906.   2,000 w., illustrated. — The author compares the driving of rolling mills by electricity with the use of steam engines. **No. 487.   C.**

Modern Foundry Construction.   David Townsend.   Paper

read before the Philadelphia Foundry Foremen Association, February, 1906. " The Iron Trade Review," April 12, 1906. 2,000 w., illustrated. **No. 488. A.**

Steel Cross Ties. W. F. Miller. Paper read before the Engineers' Society of Western Pennsylvania, Structural Section, January 25, 1906. " Proceedings " of the Society, March, 1906. 4,000 w., illustrated.— The author describes briefly the types of steel ties which are at present attracting most attention, namely, the truss steel tie, the M'Cune steel tie and the Carnegie Steel Company's steel tie. **No. 489. B.**

Molding Sand. H. E. Field. A paper read before the Pittsburg Foundrymen's Association, March 5, 1906. " The Iron Trade Review," March 15, 1906. 6,000 w. — The author discusses the composition of molding sand, the nature and properties of the ingredients, the properties of the sand, including refractoriness and strength, the relation between these properties and the chemical and physical character (shape, size of particles, etc.) of the ingredients, etc. **No. 490. A.**

The Romance of Steel and Iron in America. The story of a thousand millionaires, and a graphic history of the billion-dollar steel trust. Herbert N. Casson. " Munsey's Magazine," April, 1906. 10,000 w., many illustrations. — This article, which is the first of a series which will continue for about a year, contains a graphic description of the invention of Kelly and Bessemer, as well as sketches of the big men who took the lead in developing it. **No. 491. A.**

The Anatomy of a Steel Rail. H. C. Boynton. " Harper's Monthly Magazine," March, 1906. 3,000 w., illustrated. — A popular article describing some of the defects of steel rails, resulting from the piping of steel ingots and high finishing temperatures. **No. 492. B.**

The Removal of a Salamander from a Blast Furnace. J. J. Smith. " American Machinist," February 22, 1906. 6,000 w., illustrated. **No. 493. B.**

Heat Treatment of Cast Iron. P. Munnoch. " The Iron and Coal Trades Review," February 9, 1906. 1,800 w., illustrated. — The author describes the effect of some heat treatments upon the physical properties of cast iron. **No. 494. B.**

METALLURGICAL NOTES AND COMMENTS

William Kelly The following sketch of William Kelly's life and of his claims to the first conception of the pneumatic process for steel making are reproduced here in a slightly abridged form from a very interesting article, " The Romance of Steel and Iron in America," by Herbert N. Casson, in *Munsey's Magazine* for April, 1906.

In 1846 William Kelly (see frontispiece) and his brother bought the Suwanee Iron Works, near Eddyville, Kentucky. Kelly's father was a well-to-do landowner in Pittsburg, where it is said that he erected the first two brick houses in the city. At the time when William Kelly began to make iron he was thirty-six years old, a tall, well-set-up, muscular, energetic man, with blue eyes and close-cropped beard. In inventiveness his brain ranked high; in business ability, low. He had left a commission business and become an iron maker mainly to carry out a process which he had invented, by which larger sugar kettles were to be made. The " Kelly kettles " became well known among the Southern farmers.

He had married Miss Mildred A. Gracy, of Eddyville, and secured the financial backing of his wealthy father-in-law. His iron plant was a fairly good one, close to high-grade ore, and needing the work of about three hundred negro slaves. Mr. Kelly was strongly opposed to slavery, and tried to escape being a slaveholder by importing Chinese. He was the first employer in this country to make this experiment, and found it successful; but international complications prevented him from putting it into practice on a larger scale.

Kelly's first aim was to make good wrought iron, for his kettles and for customers in Cincinnati. His iron was refined in what was called a " finery fire," — a slow, old-fashioned process which used up quantities of charcoal.

In a year all the wood near the furnace had been burned, and the nearest available source of supply was seven miles distant — a fact with which the unbusinesslike Kelly had not

reckoned. To cart his charcoal seven miles meant bankruptcy, unless — he could invent a way to save fuel.

One day he was sitting in front of the " finery fire " when he suddenly sprang to his feet with a shout, and rushed to the furnace. At one edge he saw a white-hot spot in the yellow mass of molten metal. The iron at this spot was incandescent. It was almost gaseous. Yet there was no charcoal — nothing but the steady blast of air. Why didn't the air chill the metal? Every iron maker since Tubal-Cain had believed that cold air would chill hot iron. But Kelly was more than an iron maker. He was a student of metallurgy and he knew that carbon and oxygen had an affinity for each other. He knew what air was and what iron was, and like a flash the idea leaped into his excited brain — *there is no need of charcoal: air alone is fuel.*

It was as simple as breathing and very similar, but no human mind had thought of it before. When the air is blown into the molten metal the oxygen unites with the impurities of the iron and leaves the pure iron behind. Oxygen — that mysterious element which gives life to all creatures, yet which burns up and destroys all things; oxygen, which may be had without money in infinite quantities — was now to become the creator of cheap steel.

Kelly was carried away by the magnitude of his idea. His unrestrained delight, after months of depression, amazed every one in the little hamlet. Most of his neighbors thought him crazy. Only three listened with interest and sympathy — two English iron workers and the village doctor.

At first Kelly snapped his fingers at opposition. " I'll prove it publicly," he said. At his invitation a number of jesting iron makers from western Kentucky gathered around his furnace the following week, and Kelly, caring nothing for patents, explained his idea and gave a demonstration of it. Air was blown through some melted pig iron, agitating it into a white heat, to the amazement of the brawny onlookers. A blacksmith seized a piece of the refined iron, cooled it, and with his hammer produced in twenty minutes a perfect horseshoe. He flung it at the feet of the iron-men, who could not believe their eyesight, and, seizing a second scrap of the iron, made nails and fastened the shoe to the foot of a nearby horse. Pig iron, which cannot be hammered into anything, had been changed

into malleable iron, or something very much like it, without the use of an ounce of fuel.

Surely, the thing was too absurd. Seeing was not believing. "Some crank'll be burnin' ice next," said one. The iron-men shook their heads and went home to boast in after years that they had seen the first public production of " Bessemer " steel in the world.

Kelly called his invention the " pneumatic process," but it became locally known as " Kelly's air-boiling process." He proceeded at once to refine his iron by this method. He sent his steel, or refined iron, or whatever it was, to Cincinnati, and no flaws were found in it. Years before Mr. Bessemer had made any experiments with iron there were steamboats on the Ohio River with boilers made of iron that had been refined by Kelly's process.

But now came a form of opposition that Kelly could not defy. His father-in-law said: " Quit this foolishness or repay the capital I have advanced." His Cincinnati customers wrote: " We understand that you have adopted a new-fangled way of refining your iron. Is this so? We want our iron made in the regular way or not at all."

About the same time Kelly's ore gave out. New mines had to be dug. Instead of making ten tons a day, he made two.

He surrendered. He became outwardly a level-headed, practical, conservative iron maker and won back the confidence of his partners and customers. Then one night he took his " pneumatic process " machinery three miles back into a secluded part of the forest and set it up. Like Galileo, he said: " Nevertheless, air *is* fuel! " No one knew of this secret spot except the two English iron-workers whom he brought out frequently to help him.

Under such conditions progress was slow. By 1851 his first converter was built — a square, brick structure, four feet high, with a cylindrical chamber. The bottom was perforated for the blast. He would first turn on the blast and then put in melted pig iron with a ladle. About three times out of five he succeeded. The greatest difficulty was to have the blast strong enough, otherwise the iron flowed through the airholes and clogged them up.

His second converter was made with holes in the side, and

worked better. He discovered that he could do ninety minutes, work in ten, and save further expense in fuel. One improvement followed another. In all, be built seven converters in his backwoods hiding-place.

In 1856 Kelly was told that Henry Bessemer, an Englishman, had taken out a United States patent for the " pneumatic process." This aroused Kelly's national pride more than his desire for a monopoly, and he at once filed in the Patent Office his claims to priority of invention. The Patent Office was convinced and granted him United States Patent No. 17,628, declaring him to have been the original inventor.

Then came the panic of 1857, and Kelly was one of the thousands who toppled over into bankruptcy. To get some ready money, he sold his patent to his father for a thousand dollars. Not long afterwards, the elder Kelly died and willed his rights to his daughters, who were shrewd, businesslike women. They regarded their brother William as a child in financial matters and refused to give him his patent. After several years of unjustifiable delay, they transferred it to Kelly's children. And so, between his relations and his creditors, Kelly was brought to a standstill.

But even at the lowest point of defeat and poverty, he persevered. Without wasting a day in self-pity, he went at once to the Cambria Iron Works, at Johnstown, Pa., and secured premission from Daniel J. Morrell, the general superintendent, to make experiments there.

" I'll give you that corner of the yard and young Geer here to help you," said Morrell.

In a short time Kelly had built his eighth converter,— the first that really deserved the name,— and was ready to make a public demonstration. About two hundred shopmen gathered around his queer-looking apparatus. Many of them were puddlers, whose occupation would be gone if Kelly succeeded. It is often fear that makes men scoff, and the puddlers were invariably the loudest in ridiculing the " Irish crank."

" I want the strongest blast you can blow," said Kelly to Leibfreit, the old German engineer.

" All right," answered Leibfreit. " I gif you blenty! "

Partly to oblige and partly for a joke, Leibfreit goaded his blowing engine to do its best, hung a weight on the safety-

valve, and blew such a blast that the whole contents of the converter went flying out in a tornado of sparks. This spectacular failure filled the two hundred shopmen with delight. For days you could hear in all parts of the works roars of laughter at " Kelly's fireworks." In fact, it was a ten years' joke in the iron trade.

In a few days Kelly was ready for a second trial, this time with less blast. The process lasted more than half an hour and was thoroughly unique. To every practical iron maker, it was the height of absurdity. Kelly stood coatless and absorbed beside his converter, an anvil by his side and a small hammer in his hand. When the sparks began to fly, he ran here and there, picking them up and hammering them upon his anvil. For half an hour every spark crumbled under the blow. Then came one that flattened out, like dough — proving that the impurities had blown out. Immediately he tilted the converter and poured out the contents. Taking a small piece, he cooled it and hammered it into a thin plate on his anvil, proving that it was not cast iron.

He had once more shown that cold air does not chill molten iron, but refines it with amazing rapidity if blown through it for the proper length of time. His process was not complete, as we shall see later, but subsequent improvements were comparatively easy to make. Bessemer, by his own efforts, did not get any better " steel " in 1855 than Kelly had made in 1847.

For this exact account of Kelly's achievements I am indebted to Mr. J. H. Geer, who was his helper at Johnstown, and to others who were eye-witnesses of his earlier success in western Kentucky.

Kelly remained at Johnstown for five years. By this time he had conquered. His patent was restored to him, and Mr. Morrell and others bought a controlling interest in it. He was now honored and rewarded. The " crank " suddenly became a recognized genius. By 1870 he had received thirty thousand dollars in royalties; and after his patent was renewed he received about four hundred and fifty thousand more. After his process had been improved and widely adopted, Kelly spent no time claiming the credit or basking in the glory of his success. No man was ever more undaunted in failure and more modest in victory. He at once gave all his attention to manufacturing

high-grade axes in Louisville, and founded a business which is to-day being carried on at Charleston, West Virginia, by his sons.

When more than seventy years of age, he retired and spent his last days at Louisville. Few who saw the quiet, pleasant-faced old gentleman in his daily walks knew who he was or what he had accomplished. Yet, in 1888, when he died, it was largely by reason of his process that the United States had become the supreme steel-making nation in the world. He was buried in the Louisville cemetery. His wife is still living.

The new process was perfected by a third inventor, Robert F. Mushet, a Scotsman. He solved a problem which had baffled both Kelly and Bessemer — how to leave just enough carbon in the molten metal to harden it into the required quality of steel. Instead of frantically endeavoring to stop the process at exactly the right moment, Mushet asked:

" Why not first burn out *all* the carbon, and then pour back the exact quantity that you need? "

This, too, was a simple device, but no one had thought of it before. Since then other improvements have been added by Holley, W. R. Jones, Reese, Gilchrist and Thomas.

The new metal was soon called by the name of " Bessemer steel." Strictly speaking, it was not steel in the original use of the word. It was a new substance, very much like wrought iron. It was not hard enough to serve for all purposes. For knives, for springs, for hammers, for a thousand finer uses, steel must still be made by slower and more careful methods. The Bessemer product does the rougher work, where quantity and cheapness are essential. In an axe, for instance, the cutting edge is made of crucible steel and the rest of Bessemer steel. All the steel rails, the great beams and girders that make our skyscrapers and bridges, the plates of steamships, the wire, nails, tubes, freight-cars and innumerable things, great and small, are made of the new metal that was first produced less than sixty years ago.

It is probable that one reason for the naming of Bessemer steel was the fact that true steel was then selling at three hundred dollars a ton. The new metal might have been less highly esteemed had it been announced merely as a modified form of iron.

In 1870, both Kelly and Bessemer applied to the United

States Patent Office to have their patents renewed. The Commissioner of Patents refused to extend Bessemer's, stating that he had no right to a patent in the first place, but Kelly's was extended for seven years, on the ground that he had not yet received sufficient remuneration for his invention. As soon as it was known that Kelly's patent was to be renewed the Patent Office was fairly mobbed by objectors. Never before had there been such opposition to the renewal of a patent. The steel makers and the railroad men united in a chorus of protest. The dread of paying higher royalties drove them to attack Kelly's claims. Bessemer, whose right to royalties was now at an end, was lauded as the original inventor, while Kelly was vilified as an interloper. Out of this opposition sprang the exaltation of Bessemer and the belittling of Kelly, which deprived America of the credit for one of the world's greatest inventions.

Kelly's claim is supported not only by the United States Patent Office but by the most eminent authorities. " Kelly in America, Bessemer, Mushet and Goransson in Europe, discovered and developed the pneumatic process of treating pig iron," says Robert W. Hunt, the veteran steel expert of Chicago. James Park, one of the Pittsburg " fathers of steel," declared that " the world will some day learn the truth, and in ages to come a wreath of fame will crown William Kelly, the true inventor of the Bessemer process." Even an English writer, Zerah Colburn, records that " the first experiments in the conversion of melted cast iron into malleable steel were made in 1847, by William Kelly." And the greatest living authority on the history of American iron and steel — James M. Swank, who has been the secretary of the American Iron and Steel Association for a generation — says:

" Mr. Kelly claims the discovery of the pneumatic principle of the Bessemer process several years before it dawned upon the mind of Mr. Bessemer, and the validity of this claim cannot be impeached."

And so Henry Bessemer, who was second in the race, received ten million dollars, world-wide fame and knighthood; while William Kelly, who was first, received half a million dollars and comparative oblivion. Kelly was not to any degree embittered by his country's disregard of him. He had an unwaver-

ing conviction that everything would be made right. Shortly before his death he said to his children:

" The day will come when some one will do me justice."

Mushet fared even worse than Kelly. For him there was neither fame nor money. He lost his patent by failing to pay the necessary fees, and the steel-makers joyfully appropriated his invention without any fear of a lawsuit. In his later years he received a pension of three hundred pounds annually from Bessemer and a slight public acknowledgment of his work. Very little is known of Mushet. He will doubtless remain one of the world's unrecognized and unrewarded benefactors.

Blast Furnace and Steel Works Records. — October and March are, generally speaking, the best months of the year for production at blast furnaces and steel works. Below we summarize some outputs which were made chiefly in last October and last March at American blast furnaces and steel works. These constituted the records of the respective plants at the time. Some of the records made in October last have been broken, but the new figures are not for the moment available. While the nominal sizes of the apparatus are given, it is, of course, well understood that many other factors contribute to output: in the case of blast furnaces the size and number of tuyères, capacity of stoves and blowing engines, etc., and in the case of steel works the accessory appliances in general.

INDIVIDUAL BLAST FURNACE OUTPUTS IN A THIRTY-ONE-DAY MONTH, MADE IN OCTOBER, 1905

Name	Dimensions	Month's Output Gross Tons	Daily Average Gross Tons
Edgar Thomson H....	91 x 22	15,751	508
New Castle No. 2.....	94½ x 20	15,255	492
Lorain D...........	85 x 22	14,554	469
Edith..............	97 x 20	13,764	444
Joliet No. 3.........	80 x 20	13,369	431
Edgar Thomson B....	81 x 19½	12,664	409
Riverside B.........	100 x 21	12,611	407
Bellaire No. 2.......	75 x 18	11,435	369
South Sharon No. 2...	85 x 19	11,168	360
Niles No. 1.........	76 x 18¼	10,004	323
Emma..............	73 x 17	9,484	306
Riverside A.........	75 x 17	8,704	281
North Sharon.......	75 x 11	8,236	266
Newburgh..........	62 x 16	7,194	232
Milwaukee No. 2.....	66 x 16	6,337	204
Illinois North No. 2...	66 x 16	5,365	173

A new world's record for the output of four blast furnaces in one calendar month was made in March, 1906, by the four Duquesne blast furnaces, producing 78,120 gross tons of pig iron (not including 2,473 tons of ladle and other scrap), this being an average per furnace of 19,530 tons for the month and 630 tons per day. The previous record had been made by four of the Edgar Thomson stacks in March, 1905, while the record before that was by the four Duquesne furnaces, in October, 1904. This last-named record will be recalled as the one which was announced on the occasion of the visit of the Iron and Steel Institute to Pittsburg. These records were as follows:

FOUR OF THE EDGAR THOMSON FURNACES IN MARCH, 1905

Furnace	Dimensions	Month Output	Daily Average
D.............	90 x 22	17,982	580
E.............	90 x 22	17,745	572
J.............	90 x 22	20,244	653
K.............	90 x 22	21,271	686

THE FOUR DUQUESNE FURNACES IN OCTOBER, 1904

Furnace	Dimensions	Month Output	Daily Average
No. 1..........	100 x 22	18,402	594
No. 2..........	100 x 23	20,661	666
No. 3..........	100 x 22	17,561	566
No. 4..........	100 x 23	17,981	580

In the last seven days of March, 1906, Duquesne No. 1 produced 5,313 tons, a daily average of 759 tons. On March 20, 1905, Edgar Thomson K turned out 918 tons, its average for that day and the immediately preceding and following days being 795 tons.

The following ingot outputs have been made at converting plants, constituting at the time the records for the individual plants:

OUTPUTS OF CONVERTING DEPARTMENTS, GROSS TONS OF INGOTS

Plant	Converters	Output	Month
Duquesne................	2 10-ton	62,401	March, 1906
Ohio, Youngstown........	2 10-ton	74,698	March, 1906
Edgar Thomson..........	*4 15-ton	102,740	October, 1905
New Castle..............	2 8-ton	60,022	October, 1905
Bellaire.................	2 10-ton	34,088	October, 1905
McKeesport (Tube Co.)....	2 8-ton	30,292	October, 1905
Riverside (Tube Co.)......	2 5-ton	17,676	October, 1905

* Only three are blown at a time, one being kept always in reserve.

Following are records made for the respective open-hearth plants, all made in March, 1906. The furnaces are all nominally of 50-ton capacity, and the month's output is given in gross tons of ingots.

OUTPUTS OF BASIC OPEN-HEARTH PLANTS

Plant	Number of Furnaces	Month's Output
Duquesne............	14	50,297
Clairton.............	12	53,014
Donora.............	12	46,469
South Sharon........	12	52,015
Total.............	50	201,795
Per furnace for month.................		4,036
Approximate per 24 hours.............		150

Nickel-Vanadium Steels.* — We have reviewed in these columns the reports of M. Leon Guillet upon the properties of certain nickel steels, and also his researches upon vanadium alloy steels. We now have, in a recent issue of the " Revue de Métallurgie," a study of certain alloy steels containing both nickel and vanadium, together with determinate proportions of carbon, the results of which are interesting.

In his earlier researches M. Guillet emphasized the importance of specifying the carbon content of an alloy steel, in addition to the percentage of metallic alloy, and most of his investigations have been conducted upon two groups of steels, one of moderately low carbon, 0.120 to 0.200 per cent and the other a high-carbon steel, about 0.800 per cent.

Briefly, the properties of the nickel steels in these two groups are as follows: with a steel of 0.120 carbon there is a pearlitic nickel steel, containing up to 10 per cent of nickel; a pure martensite steel, with a nickel content from 10 to 27 per cent and a gamma-iron steel with a nickel content of more than 27 per cent.

With a steel of 0.800 carbon the alloy has a pearlitic character up to 5 per cent of nickel, while the martensitic structure exists when the nickel content lies between 5 and 15 per cent, and the gamma-iron alloy appears for nickel contents above 15 per cent.

The pearlitic nickel steels have nearly the same properties

* " Engineering Magazine," April, 1906.

as carbon steels, the tensile strength gradually increasing with the increase in nickel content, these steels being also more homogeneous and less brittle than carbon steels. The martensitic steels have a very high tensile strength and elastic limit, low elongation, and are brittle and extremely hard. The gamma-iron steels possess a very low elastic limit, a great elongation and a remarkable resistance to shock.

The vanadium steels are also divided into two groups, according to their carbon content, and each of these groups into three classes, according to the proportion of vanadium.

The first class of the vanadium steels is that having a pearlitic structure, this appearing in steels of 0.200 carbon content with percentages of vanadium up to 0.7 per cent, while for steels of 0.800 carbon the limit of vanadium content is 0.5 per cent. When the proportion of vanadium in the 0.200 carbon steel lies between 0.7 and 3 per cent the steel is of a pearlitic structure containing a special constituent, the vanadium being in the state of a carbide, while when the percentage of vanadium exceeds 3 per cent for the low-carbon steel and 7 per cent for the high-carbon steel the whole of the carbon is in the state of a carbide.

The properties of the vanadium steels of the three groups are summarized as follows:

So long as the vanadium exists in the state of solution in the iron the tensile strength and the elastic limit are increased, the elongation and reduction in area of the test piece slowly diminishing, while the brittleness and hardness are very slightly increased with the increase in the percentage of vanadium. When the vanadium is in the state of carbide and there yet remains any pearlite in the alloy, the tensile strength and the elastic limit diminish, and the brittleness and hardness are also reduced with the increase in the vanadium content. When all the carbon is in the state of a carbide the alloy possesses properties which vary but slightly with changes in composition. The tensile strength and the elastic limit are both low, with a fair degree of elongation, the steel being at the same time very brittle.

Having thus ascertained the properties of the nickel and the vanadium alloy steels, considered separately, M. Guillet has proceeded to investigate the influence of these elements

when used jointly. For this purpose he has had prepared at the steel works at Imphy a series of such alloys, following, as before, the plan of studying two main groups, one having a carbon content of 0.200 per cent and the other 0.800 per cent.

With the introduction of another element the possible combinations naturally increase in number, but M. Guillet has succeeded in weeding out those which are unsuitable for practical purposes, and then determined carefully the properties of the remaining alloys.

Taking up first the normal steels, or those which have not been subjected to any special heat treatment for the purpose of annealing or tempering, these may be divided into six classes, these including:

(1) Pearlitic steels, (2) steels containing carbide and ferrite, (3) martensitic steels, (4) steels containing martensite and carbide, (5) gamma-iron steels, (6) gamma-iron and carbide steels.

M. Guillet gives numerous microphotographs of these alloys, and data and results of mechanical tests and shows that a conspicuous effect of the addition of vanadium to the nickel steels is to moderate the abruptness of the changes between the several classes.

Leaving aside a number of the alloys which are of interest to the scientific investigator alone and confining this review to the steels which have immediate uses in the constructive arts, we note first, that in the pearlitic steels, those containing, for 0.200 carbon, from 2 to 12 per cent of nickel, the tensile strength and the elastic limit are both materially increased by the addition of small percentages of vanadium. In no case should the vanadium content exceed 1 per cent, the best results being secured by the use of 0.7 to 1 per cent of vanadium. Thus a steel containing 0.200 carbon, 2 per cent of nickel and 0.7 per cent vanadium showed a tensile strength of 91,000 pounds, an elastic limit of 70,000 pounds and an elongation of 23.5 per cent. With 1 per cent of vanadium, the ultimate tensile strength increased to 119,500 pounds and the elastic limit to 91,000 pounds, the elongation falling to 22 per cent. A nickel steel of 0.200 per cent carbon and 12 per cent nickel gave, with 0.7 vanadium, a tensile strength of over 200,000 pounds per square inch, and an elastic limit of 172,000 pounds, the elongation being 6 per cent,

while with 1 per cent of vanadium the tensile strength rose to 220,000 pounds, and the limit of elasticity to 176,000 pounds, the elongation remaining unchanged. When the vanadium content is increased above 1 per cent the tensile strength falls off and the material begins to show evidence of brittleness.

Similar effects are produced for steels of the higher carbon, but in a lesser degree.

When the nickel-vanadium steels are subjected to a tempering process the beneficial effects of the vanadium are still further emphasized. The tempering experiments of M. Guillet were conducted by heating the steel to a temperature of 850° C., and cooling in water at 20° C. These experiments showed that a material influence was exercised upon the pearlitic steels. The tensile strength and the elastic limits were increased, being nearly doubled for the low-nickel content. Thus the 0.200 carbon steel with 2 per cent of nickel, untempered and containing 0.7 per cent of vanadium gave, as we have said, a tensile strength of 91,000 pounds, with an elastic limit of 70,000 pounds. The same steel, tempered from 850° C., showed a tensile strength of 168,000 pounds and an elastic limit of 150,000 pounds, the resistance to shock and the hardness being also increased. This is one of the most notable features about these alloy steels, and should be given especial attention by engineers and constructors. The martensitic steels are also hardened by tempering, but the effect is not so marked with the pearlitic steels.

M. Guillet's paper contains much that will interest the engineer and metallurgist, but for the constructer the principal points to be gained from his investigations are these:

The addition of vanadium is of value, so far as can be seen at present, to steels containing from 2 to 12 per cent of nickel, and in no case should more than 1 per cent of vanadium be used. The result is to increase both the tensile strength and the elastic limit, especially if the steel is tempered by heating to about 850° C. and cooling in water at atmospheric temperature.

These results are what might be expected from a consideration of the effects of nickel and of vanadium upon steel considered separately. An especial feature of interest is that very small additions of vanadium may be used to produce very marked effects upon nickel steels.

The Plethora of Scrap.*— Rarely has the market in any iron and steel commodity moved more at variance with expectations than has the scrap market in the past few months. Last fall found the iron trade in expectation of a very busy winter, with good demand for all raw materials. Ample preparations were made by both dealers in and consumers of scrap for the heavy consumptive demand and the usual curtailment of movement into the market of scrap, consequent upon bad weather. As the winter period has progressed, scrap has become more plentiful and prices have steadily fallen. It is fashionable in some quarters to blame the slump upon the weather. There is more in it than that. We are now on the verge of spring, and if the slump has been caused simply by scrap reaching the market sooner than expected, a correspondingly smaller quantity of scrap is going to find its way into the market during the next few months. Only so much scrap is produced, conditions as to scrap production not having changed, and the material can come into the market but once. A reaction then should be in order, but the market is scrutinized in vain for premonitions of it.

The fact is simply that scrap is not the necessity to the basic open-hearth steel industry which in the early days it was supposed to be. In 1899, when we made two million tons of basic open-hearth steel ingots, the country was scoured for scrap, and material was used which had lain for years where it had been abandoned. Last year our production was probably about quadrupled, and there is plenty of scrap left.

Two or three years ago the Carnegie Steel Company was a buyer of scrap. Then it stopped. The Clairton Steel Company was a large buyer of scrap. It was absorbed by the Carnegie Steel Company, yet the latter did not become a buyer. The company increased the capacity of its old plants and started the Donora plant and still did not become a buyer. It has instead been a seller, disposing of a large part of its own low-phosphorus scrap to outsiders. Another Pittsburg concern has become a large producer of basic open-hearth steel, and instead of buying scrap it has been trading large quantities of its own scrap for crude steel.

The ordinary direct metal process and the Talbot, Monell

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* " The Iron Trade Review," March 15, 1906.

and other processes, together with the facility with which scrap is made in both Bessemer and open-hearth plants by liberal cropping, have killed the necessity for steel manufacturers to use large quantities of scrap, or any quantity of old material at all, except possibly in the case of detached open-hearth plants. Even operating under the open-hearth process alone, with the adjunct Bessemer vessel, the leading southern steel interest has been able to dispose of considerable quantities of its own scrap.

The elimination of the necessity for using scrap has reduced the problem to one of cost. It has been a pet theory of scrap dealers to regard heavy melting stock as worth a price involving a certain proportion to pig iron, which is a true enough principle, if the ratio is the correct one and if the value of pig iron be properly taken. The principal fallacy in the argument lies in assuming that the value of pig iron, to the possible buyer of scrap, is the market price of pig iron. It is not the market value, but the cost of producing the pig iron, and in times like these there is a very important disparity. The fact that certain producers of basic open-hearth steel, who do not buy scrap, do occasionally buy pig iron in the open market does not vitiate this argument. The reason they buy pig iron occasionally, and not scrap, is " another story."

Refractory Furnace Linings.* — For furnaces it is necessary to use refractory linings, and for convenience these should be in brick form. Generally, for ordinary purposes, fireclay bricks are used, in many cases low first cost being the primary consideration, the result often being that continual repairs are called for. This is not at all economical, of course, as not only have materials and labor to be paid for, but the loss of use of the furnace under repair has to be taken into consideration, this latter item often causing a greater financial loss than that caused by the actual cost of the repairs. For this reason, if for no other, the cost of a furnace (including repairs) over a fairly long period should be taken into consideration and that which shows the least annual cost will be found to be both the cheapest and the most economical.

Besides the bricks, the jointing material must also be con-

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* Walter J. May in " The Mechanical World," February 9, 1906.

sidered and with this it must be remembered that more than one point has to be taken into consideration. In the first place, it is necessary that the material be soft and well soaked,— fireclay should be soaked not less than twenty-four hours, — so that a thin joint can be made, and also to insure that the joint is a sound one; and in the second place, it is necessary that the jointing material shall not be of such a content as to act as a flux to the bricks. Thus with fireclay bricks a good, and as nearly as possible non-siliceous, fireclay should be used; with silica bricks a siliceous material as free from iron and alumina as is obtainable, and very finely ground, will be the proper thing, while with magnesite bricks finely ground magnesite plus a little binding material, such as china-clay, will be best. With alumina bricks, ground alumina should only be used, siliceous matters not being desirable. All the mortars should be well soaked and be used in a more or less sloppy state to insure close and thin joints, and they should be soaked for a sufficient time.

Common firebrick will stand fairly in flues and where there is no great heat, but with much heat they fuse and grow larger, causing deformation of the structure. The best forms of firebrick will stand fair heats, as in brass furnaces, but these also grow, while if there happens to be any fluxing matters in the jointing material, or fuel, the bricks will fuse more or less. It is not often that clay bricks scale off unless they be strongly fired while wet, this being a fault in practice rather than with the material itself.

Silica bricks will stand considerable heat if well made, but they must contain some amount of fluxing matter in the binding material. When properly put together, so that only a smooth face is presented to the fire, however, silica bricks will stand most of the heats used in the foundry or workshop, provided the bricks are of good quality. Necessarily they are more expensive than the lower grades of fireclay bricks, but they are worth the extra cost.

Magnesite bricks or blocks will stand any heat which will be found in the foundry or workshop, but they scale off badly, particularly where the furnaces are used intermittently. At the same time, the cost of such blocks is worth incurring for parts of furnaces exposed to considerable heat,— the melting

zone of the cupola and the like, — as the blocks will not fuse to any extent. Provided a good binding material was used, and one which would not be injurious to the refractory character of the magnesite, the bricks would be good enough for almost every purpose where highly refractory bricks are used.

Alumina bricks will, if properly made, stand intense heats, but usually there is too much silica and iron in their composition. Badly made, they scale considerably, and some the writer has tried were not much better than ordinary building bricks, so far as withstanding heat was concerned. Others stood very well, and it seems to the writer that the process of manufacture has a great deal to do with the matter. In fact, the Morgan Crucible Company are bringing out a brick that stands great heat without flaking or growing, and in the melting zones of cupolas, and other furnaces, they are very good, and certainly are worth trying. Of course, they are not cheap in first cost, but in the long run they are both cheap and economical, which, in the writer's opinion, is what should be aimed at in all fire work.

It must always be remembered that with all firebricks the edges go first, and particularly is this the case where the brick-setter is not careful in jointing and permits the face of the work to become unlevel. If one had a furnace — a brass furnace, for instance — lined with smooth slabs of firebrick without joints save at the angles, there would be far less wear and tear and fewer repairs than with the ordinary bricks, as the fire would have only a flat surface to attack. In fact, if it was a possibility to have all furnaces in such a form as to only present unbroken surfaces to the fire they would be more durable and lasting. Probably for this reason the practice of lining many furnaces with ganister is so much liked, as it to some large extent overcomes the trouble caused by the edges of the bricks being attacked by the fire.

The question of expansion or growing of ordinary firebricks cannot well be determined otherwise than by making provision for such expansion where possible, and by holding in some classes of furnaces with plates and tie-rods. If, however, a more regular and homogeneous body was secured with a good many brands of clay firebrick there would be less trouble in working furnaces where they are used. A firebrick should have a fairly

regular structure when broken, and not look like so much badly pressed cheese curd. There may be low first cost with these roughly made bricks, but this means eventual cost for repairs as a rule.

Of course it is presupposed that ordinary building mortar composed of lime and sand — and often other things — will not be used in fire work, and equally it is supposed that the brick-setters will know how to work with clean fireclay, otherwise peculiar results may be obtained, particularly where high temperatures are being dealt with. Men who know their work are necessary, even although they are only bricklayers.

Drift Towards Open-Hearth Rails.* — One of the most important announcements is that the immense steel-rail mill to be erected near Chicago by the steel corporation will make open-hearth rails instead of Bessemer. This is important for two reasons. It shows that open-hearth rails are to be the coming type and that Chicago will be the site of the first plant that will construct them on a scale that is large, considering the total production of steel rails in the country. Prior to 1903 the output of open-hearth rails in the United States never reached 25,000 tons in any one year. In 1903 the product was 45,054 tons; in 1904, 145,883 tons; in 1905, 183,264 tons, against 3,188,675 tons of Bessemer, and this year the output will probably show a slight increase. The principal tonnage is now made at the Ensley, Ala., plant of the Tennessee Company. This producer could sell its output many times over and is operating at fullest capacity. Experiments made by the Pennsylvania Railroad prove the superiority of open-hearth over Bessemer rails. The report has been circulated within the past few days that this railroad company would specify its entire rail requirements in open-hearth product if it were procurable. There is no doubt that the same preference would be shown by other large users of rails had they the opportunity to make choice, for the same considerations apply to rails that do to structural material and other finished steel products into which open-hearth steel is now shaped.

But there is no mill in the North now making open-hearth steel rails in scarcely any other way than experimentally. It

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* " The Iron and Machinery World," March 24, 1906.

is said, however, that the Republic Mill, at Youngstown, may produce open-hearth rails when its open-hearth plant is completed, and also that the Bethlehem Steel Company's ambitious plans for a rail mill contemplate open-hearth product. The steel corporation's mills near Chicago will scarcely be in readiness to roll rails next year, but for 1908 present prospects are much more favorable. However, the construction will be pushed just as rapidly as the magnificent scale on which plans must be laid will permit, and, once completed, this steel-rail plant must be for many years the model in the world, both for tonnage produced and the quality of product. For the first time Western railroad companies generally will then be given the opportunity to buy a considerable portion of their rails of open-hearth structure.

American Foundrymen's Association. — Announcement is made by the secretary of the Tenth Convention of the American Foundrymen's Association, to be held in Cleveland, Ohio, June 5, 6 and 7, 1906.

A cordial invitation has been extended to the members of the Association by the foundry and manufacturing interests of the Forest City. An attractive series of papers has been promised and the hospitality of the great foundry center of Lake Erie will leave nothing to be desired.

Special arrangements for the entertainment of the ladies are being provided, and all foundrymen are invited to attend.

REVIEW OF THE IRON AND STEEL MARKET

There has been no very important change in the iron and steel situation since last report. Buying has been rather moderate in volume, and has not perhaps fully equaled production, which is at an enormous rate, the greatest the country has yet seen. Furnaces and mills are, however, well filled with business and a buying movement of larger proportions is expected to start in May. Prices are in the main unchanged, pig iron being a trifle lower, on an average. Fears were felt early in April that a general downward movement in pig iron was imminent, but the market has since stiffened and this danger is probably averted. During the winter the condition was unsound, in that the scarcity and the high prices might be attributed to the fear of bad weather, and when spring came the market had to establish its basis afresh. It is now fairly well settled that the basis will not be materially lower than that of the winter.

The buying of rails has been quite heavy, despite the fact that the mills were already sold for nearly the entire year. Several producers, including Tennessee, Colorado and Illinois, are practically out of the market for 1906 deliveries, while Carnegie still has unsold tonnage. The Tennessee company has opened its books for 1907 deliveries, at an advance of a dollar a ton to $29, f. o. b. Birmingham, and has already booked tonnage running well into six figures. The other rail mills will probably open their books shortly for 1907 business, although it is early to do so, but will doubtless leave the price at $28, at which figure it has been since the spring of 1901. These mills will not follow the Tennessee company's example by advancing the price, but rather welcome the establishment of a higher price on open-hearth rails, as they recognize they must ultimately come to making open-hearth rails themselves and it will be quite an advantage to them to have a differential ready made for them.

The cotton tie market was formally opened Thursday, April 5, at last year's price, 85 cents per bundle, and the season's

business, estimated at some 1,750,000 bundles, or about 35,000 gross tons, was closed in a few days.

On Tuesday, April 10, the American Sheet and Tin Plate Company advanced its price on tin plate 10 cents per box, chiefly because of the high price of pig tin, which has broken all high marks for more than half a century.

Pig Iron. — There has been very heavy buying during the month of forge and foundry grades by cast-iron pipe interests in all districts, their total purchases probably running well into six figures. Ordinary foundries have been more moderate buyers, generally for second quarter, although a few purchases have been made for the second half. In steel making pig the business has been rather light. Some basic has been bought in the East for second half, while in the Chicago district inquiry for basic has come up. In the Pittsburg district basic has been very quiet. In standard Bessemer very little has been done, and that only for early delivery. The Cambria Steel Company took 10,000 tons of Bessemer from W. P. Snyder & Co. and the United States Steel Corporation from 15,000 to 18,000 tons from the Bessemer Furnace Association, both lots being for April delivery and at $17.25, valley. The steel corporation also took a few thousand tons of basic, at $17.00, valley. Good business is being done in the western market in malleable Bessemer. Pig iron in the East and steel making pig in the Central West are practically unchanged from last report. Foundry and forge grades in the Central West and West are a trifle lower, while the southern market, after having a weak spell early in the month, has recovered, and is now probably firmer than a month ago. While we quote the general southern market at $14.00, Birmingham, against $13.75 a month ago, it is not certain but that some detached furnaces would still make the old price. We revise prices as follows: F. o. b. valley furnace: Bessemer, $17.25; basic, $17.00; No. 2 foundry, $16.50 on very desirable orders for extended delivery, $16.75 to $17.00 on small lots; gray forge, $15.65 to $15.75. Delivered Pittsburg: Bessemer, $17.10; basic, $17.85; No. 2 foundry, $17.35 to $17.85; gray forge, $16.50 to $16.60. Delivered Chicago: Northern No. 2 foundry, $18.75 to $19.00; malleable Bessemer, $18.80 to $19.00; Lake Superior charcoal, $19.50 to $20.00. Delivered Philadelphia: No. 2 X foundry, $18.50 to $18.75; standard gray forge, $16.50 to $16.75.

Freight: Valleys to Pittsburg and Cleveland, 85 cents; to Chicago, $2.30; Birmingham to Cincinnati, $3.00; to Chicago, $3.90; to Pittsburg, $4.60; to Philadelphia by all-rail, $4.75; to Philadelphia by rail and water, $4.00. Prices on foundry iron delivered Philadelphia are quoted 25 cents higher than a month ago, the market being excited on account of some slight loss of production through the anthracite strike, but this condition is probably only temporary.

Ferro-Manganese. — The market is quiet, but it is fairly well settled that $85 or higher will have to be paid for deliveries over the second half. Prompt lots continue to command a considerable premium.

Steel. — The market continues quiet, but is about as firm as it was. Deliveries are not altogether satisfactory, particularly on sheet bars. After May 1 the Carnegie Steel Company's Ohio mill at Youngstown will be kept exclusively on rails. While it was on sheet bars, to March 18, last, and since then, while it has been on rails, a portion of the product has been 4-inch and small billets, say from 600 to 800 tons daily out of a total of about 2,500 tons daily of finished product, but after May 1 the entire output will be rails. This will increase the scarcity of small billets. Prices are practically unchanged, at $27 for Bessemer billets, $28 for open-hearth billets and $28 for sheet bars, all f. o. b. Pittsburg.

Plates and Shapes. — The situation is unchanged. A fair tonnage of shape business is being taken, mills being fully sold up until nearly the close of the third quarter. In plates the large mills have a round tonnage through the year on steel car business, and have enough other business to fill them completely for sixty days. Some of the small mills are not filled, and are anxious for tonnage, but prices remain firm on the basis of 1.60 cents for plates, tank quality, and 1.70 cents for beams and channels 15-inch and under.

Merchant Bars. — The bulk of the agricultural implement tonnage in steel bars was closed prior to April 14, for the season beginning next July, the mills having given the large interests until that date to close at a concession from the open market price of 1.50 cents, which was first put out on February 28, 1905. This concession is understood to have been to 1.40 cents, and, therefore, is slightly less than the concession made on this

business a year ago. Iron bars are lower in all markets. At Pittsburg 1.60 to 1.65 cents delivered can be done, equal to 1.55 to 1.60 cents, f. o. b. Youngstown; at Philadelphia very desirable orders are accepted at 1.63½ cents; at Chicago a basis equal to steel bars has been established, mills making delivered prices equal to 1.50 cents, f. o. b. Pittsburg, or 1.66½ cents, delivered Chicago.

Sheets and Tin Plates. — New business continues very light, but mills are very well sold up and are behind in deliveries in many cases. As noted, tin plates were advanced 10 cents a box by the leading interest on April 10, and the advanced price has become the market. Early in the month there was a little shading in sheets by a few western jobbers who were overbought, but this condition has disappeared. We quote tin plates at $3.60 for 100-pound coke plates, f. o. b. mill, Pittsburg district, and sheets at 2.40 cents for black and 3.45 cents for galvanized, same delivery.

Scrap. — The market sagged early in the month, but has since become firmer in tone. For delivery to Pittsburg a little heavy melting scrap might be picked up at $14.25, but for delivery to points just west of Pittsburg the market is $14.50 to $15.00. For delivery in the Pittsburg district, cast borings are about $8.25, wrought turnings $12.00 and sheet scrap $13.50.

Connellsville Coke. — The market is firm for prompt lots at $2.40 to $2.50 for furnace and $3.00 to $3.15 for 72-hour foundry, f. o. b. ovens.

STATISTICS

Production of Open-Hearth Steel in the United States in 1905.* — The American Iron and Steel Association has received complete statistics of the production of open-hearth steel ingots and castings in the United States in 1905.

Total Production.— The total production of open-hearth steel ingots and direct castings in the United States in 1905 was 8,971,376 gross tons, against 5,908,166 tons in 1904, an increase of 3,063,210 tons, or over 51.8 per cent. The production was much larger than in any preceding year, and was only 1,969,999 tons less than the production of 10,941,375 tons of Bessemer steel ingots and castings during the same year. The year of next largest production of open-hearth steel was 1904. When the collection of the statistics of the production of crucible and miscellaneous steel ingots and castings is completed it will be found that the total production of all kinds of steel ingots and castings in this country in 1905 will exceed 20,000,000 gross tons.

The following table gives the production of open-hearth steel ingots and castings by states since 1902, in gross tons:

States — Gross Tons	1902	1903	1904	1905
New England	179,923	169,209	195,901	239,282
New York and New Jersey	92,763	104,598	165,986	348,072
Pennsylvania	4,375,364	4,442,730	4,306,498	6,471,818
Ohio	278,854	369,349	480,906	687,392
Illinois	435,461	422,919	358,215	617,625
Other states	325,364	321,106	400,660	607,187
Total	5,687,729	5,829,911	5,908,166	8,971,376

The open-hearth steel made in 1905, including both ingots and castings, was produced by 111 works in 17 states — Massachusetts, Connecticut, Rhode Island, New York, New Jersey, Pennsylvania, Delaware, Maryland, Alabama, Ohio, Indiana,

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* " Bulletin of the American Iron and Steel Association," March 15, 1906.

Illinois, Michigan, Wisconsin, Missouri, Colorado and California. Delaware and Michigan, neither of which made open-hearth steel in 1904, appear among the producers in 1905, and Tennessee, which was a producer in 1904, is omitted from the list of producers in 1905.   One hundred and sixteen works in 16 states made open-hearth steel in 1904 and 111 works in 17 states made open-hearth steel in 1903.

Basic and Acid Steel.— In 1905 there were 7,815,728 tons of open-hearth steel made by the basic process and 1,155,648 tons by the acid process, while in 1904 the production by the basic process amounted to 5,106,367 tons and by the acid process to 801,799 tons.   This is a gain in production in 1905 over 1904 by the basic process of 2,709,361 tons and by the acid process of 353,849 tons.   In 1903 there were made 4,734,913 tons of open-hearth steel by the basic process and 1,094,998 tons by the acid process.

The following table gives the production by states of both basic and acid open-hearth steel ingots and castings in 1905. Pennsylvania made 70.3 per cent of the total production of basic steel ingots and castings in 1905 and 84.1 per cent of the total production of acid steel ingots and castings, against 71.8 per cent of basic and 79.6 per cent of acid ingots and castings in 1904.   Ohio and Illinois were the next largest producers of basic ingots and castings in each of these two years.   The production of basic and acid open-hearth steel was first separately ascertained by us for the year 1896.

States — Gross Tons	Basic Open-Hearth Steel	Acid Open-Hearth Steel	Total Gross Tons
New England	175,713	63,569	239,282
New York and New Jersey	320,348	27,724	348,072
Pennsylvania	5,499,101	972,717	6,471,818
Ohio	643,323	44,069	687,392
Illinois	613,192	4,433	617,625
Other states	564,051	43,136	607,187
Total	7,815,728	1,155,648	8,971,376

Ingots and Castings.— The production of open-hearth steel ingots in 1905, excluding castings, amounted to 8,444,836 tons, against 5,605,332 tons in 1904, an increase of 2,839,504 tons or over 50.6 per cent.   The production of castings alone in 1905

amounted to 526,540 tons, against 302,834 tons in 1904, an increase of 223,706 tons, or 73.8 per cent.

Basic Acid and Ingots.— The following table gives the production of basic and acid open-hearth steel ingots in 1905 by states, direct castings being omitted:

States — Gross Tons	Basic Ingots	Acid Ingots	Total Gross Tons
New England, New York and New Jersey	471,382	56,765	528,147
Pennsylvania	5,482,432	755,098	6,237,530
Ohio, Illinois and other states	1,655,755	23,404	1,679,159
Total	7,609,569	835,267	8,444,836

Basic and Acid Castings. — The total production of open-hearth steel castings in 1905, as already stated, amounted to 526,540 gross tons, of which 206,159 tons, or over 39 per cent, were made by the basic process, and 320,381 tons, or almost 61 per cent, were made by the acid process. The production in 1905 was much the largest in our history and exceeded that of 1903, the next largest year, when 400,348 tons were made by 126,192 tons, or over 31 per cent. In 1904 the production of open-hearth steel castings amounted to 302,834 tons, of which 98,919 tons were made by the basic process and 203,915 tons by the acid process. The increase in the production of castings in 1905 as compared with 1904 amounted to 223,706 tons, or 73.8 per cent, the increase in basic castings amounting to 107,240 tons, or over 108 per cent, and in acid castings to 116,466 tons, or over 57 per cent.

The following table gives the production of open-hearth steel castings by both the basic and acid processes in 1905 by states:

States — Gross Tons	Basic Castings	Acid Castings	Total Gross Tons
New England, New York and New Jersey	24,679	34,528	59,207
Pennsylvania	16,669	217,619	234,288
Ohio, Illinois and other states	164,811	68,234	233,045
Total	206,159	320,381	526,540

British Statistics for 1905.* — The output of Bessemer steel ingots in the United Kingdom in 1905, as ascertained in the British Iron Trade Association direct from the manufacturers,

* " Bulletin of the American Iron and Steel Association," March 15, 1906.

amounted to 2,009,712 tons, which compares with 1,781,533 tons in 1904 and 1,910,018 tons in 1903. The increase in 1905 was 228,179 tons over 1904 and 99,694 tons over 1903. The output of acid steel ingots in 1905 was 11,493 tons less than that of 1904, while the output of basic steel ingots was 239,672 tons more. The production of acid steel in 1905 was 1,117,731 tons and the production of basic steel was 891,981. During 1905 there were 19 works which made Bessemer steel ingots in Great Britain, of which 7 produced between 100,000 and 200,000 tons each. One plant only made over 200,000 tons. The British output of Bessemer steel rails in 1905 was 951,552 tons, as compared with 916,374 tons in the previous year.

The production of coal in Great Britain in 1905 under the Coal Mines Regulation Act was 236,111,150 tons, against 232,411,784 in 1904.

Iron Production of Spain.* — The production of iron ore in Spain during 1905 was the largest in the history of the kingdom. According to advance sheets of the mineral statistics, the output was 9,395,314 tons, against 7,964,748 tons in 1904 and 9,230,000 tons in 1899, up to that time the banner year. Practically 90 per cent of the ore was exported, Great Britain taking 5,845,895 tons, Holland 1,806,328 tons, Belgium 314,203 tons, France 251,716 tons, United States 213,203 tons, Germany 140,471 tons, and other countries less than 20,000 tons.

Pig iron was turned out by 18 works with an aggregate tonnage of 383,100, slightly less than in the previous year. The leading producer was the Soc. Altos Hornos de Vizcaya, with 209,000 tons to its credit. The other works were exceedingly small, many of them producing only charcoal iron.

The production of Bessemer steel showed an increase from 93,100 tons in 1904 to 113,664 tons in 1905, the output of the Altos Hornos works and a small steel foundry. A number of works turned out Siemens steel, the year's output being 124,200 tons, against 100,659 tons in 1904. The total steel output was 238,000 tons, of which the Altos Hornos works made 168,500 tons. Puddled iron lost slightly in comparison with 1904, the production for the past year being 52,250 tons.

The expansion of the output of iron and steel in Spain has been very rapid. Since 1898 the output of pig iron has increased from 262,000 tons to 383,000 tons, Bessemer steel from 54,000 tons to 113,000 tons, Siemens steel from 58,000 tons to 124,000 tons and the output of rolled and forged iron and steel from 155,000 tons to 308,000 tons.

* " Iron Trade Review," April 12, 1906.

RECENT PUBLICATIONS

Traité Pratique de la Fonderie du Fer, by G. Van der Haeghen and L. Ledent. 784 5 × 8-in. pages; illustrated; paper covers. Charles Desoer. Liége, Belgium. 1905. — The American foundryman should not too hastily infer that he has nothing to learn from European practice if he desires to avoid the penalty brought about by egotism and which in this case might be expressed in dollars and cents. While the reading of a book like the one under review and which is probably typical of European foundry practice may in many ways bring out the superiority of American methods, the careful and impartial student will undoubtedly derive from it instruction and profit. It will suggest to him possible improvements in some phases of foundry work, as, for instance, in methods of tempering sand by machinery, in mixing up blacking, in the use of fore-hearth cupolas, etc.

La Fonderie Moderne, Bibliothèque du Mois Scientifique et Industriel. 686 6 × 9½-in. pages; illustrated. Vve. Ch. Dunod. Paris. Price, 2.50 francs. — This pamphlet deals briefly with the principal mechanical and chemical features of foundry work. While necessarily incomplete, the treatment includes satisfactory descriptions of some modern improvements, such as the use of pyrometers, recent molding machines, use of thermit, the closing of blowholes by the oxy-hydrogen blow pipe, sand blasting, etc.

The Mineral Industry. Volume XIII. 589 6 × 9-in. pages; illustrated. "The Engineering and Mining Journal." New York and London. 1905. Price, $5.00. — The last number of this valuable annual contains the usual amount of accurate statistical data regarding the mineral and metal production of the United States, and many interesting pages dealing with the use of the metals, progress in their methods of manufacture, etc. Prof. R. H. Richards contributes his annual review of "Progress in Ore Dressing and Coal Working." J. F. Kemp contributes a "Review of the Literature on Ore Deposits in 1904

and 1905." Short articles are devoted to special features of the mineral and metal industry in Alaska, the Klondike, Arizona, California, Nevada, eastern states of Australia, western Australia and the Transvaal. The practice, so long adhered to by the publishers, to include a number of articles written by experts on special subjects closely related to the metal industry, has been abandoned in the present volume.

Modern Machine Shop Construction, Equipment and Management, by Oscar E. Perrigo. 343 7 × 10-in. pages; illustrated. The Norman W. Henley Publishing Company. New York. 1906. Price, $5.00. — This is essentially a practical book, designed for those interested in the construction, equipment or management of the machine shop. In the first part of the book the author describes and illustrates building of approved form and arrangement, in the second part he deals with the equipment of the shop with modern tools, machines and appliances, and in part three with the management, describing, to use the author's words, " a plain, concise, accurate and common-sense system of management, and of time and cost keeping." A considerable portion of the subject matter was published in " Machinery," " The Iron Trade Review " and " The Foundry." The book is well printed, illustrated and bound, and it should prove valuable to the many architects, engineers and superintendents interested in machine shop in their various capacities.

A Treatise on Producer-Gas and Gas-Producers, by Samuel S. Wyer. 296 6 × 9-in. pages; illustrated. " The Engineering and Mining Journal." New York and London. 1906. Price, $4.00. — Engineers and metallurgists have in recent years devoted much attention to improvements in the production of " producer-gas," both as to the construction of the producers and the quality of the gas obtained, and a book like the one we have before us in which the results of this recent activity are systematically and clearly described is certain to be welcomed by a large class of interested persons. The subject is divided into thirty chapters, bearing the following titles: Fundamental Physical Laws and Definitions; Fundamental Chemical Laws and Definitions; Thermal and Physical Calculations; Commercial Gases; Status of Producer-Gas; Classification of Gas-Producers; Manufacture and Use of Producer-Gas; Use of Steam in Gas-

Producers; Carbon Dioxide in Producer-Gas; Efficiency of Gas-Producers; Heat Balance of the Gas-Producers; Fuel Requirements; History of Gas-Producers; American Pressure Producers; American Suction Gas-Producers; Gas Cleaning; By-Product Gas-Producers; By-Product Coke-Oven Gas-Producers; Producer-Gas for Firing Ceramic Kilns; Producer-Gas for Firing Steam Boilers; Wood-Gas-Producers; Removal of Tar from Gas; Gas-Producer Power-Plants; Operation of Gas-Producers; Testing Gas-Producers; Future of the Gas-Producer; Gas-Poisoning.

The book is well printed on good paper and it has an attractive and substantial cloth binding.

A Pocket Book of Mechanical Engineering, by Charles M. Sames. 168 4 × 7-in. pages; illustrated; flexible covers. Charles M. Sames. Jersey City. 1905. Price, $1.50. — This small-size and relatively low-price pocket book includes a large amount of information of value to engineers and students. The treatment comprises tables, data, formulas, succinct statements of theory, illustrative examples, and graphical methods. The concise form of the book and its up-to-date character are its most attractive features.

American Men of Science, edited by J. McKeen Cattell. 364 7½ × 10-in. pages. The Science Press. New York. 1906. Price, $4.00. — This biographical directory of American men of science was begun as a manuscript reference list for the Carnegie Institution of Washington. In the directory are included the records of more than four thousand men of science in North America in the fields of natural and exact sciences. Some investigators are included, however, whose work has been chiefly in engineering, medicine or other applied sciences, but this is because they are supposed to represent work which has contributed to the advancement of pure science. A star is prefixed to the subject of research in the case of about a thousand of the biographical notes, thus yielding, in the editor's opinion, a list of the thousand leading American men of science. To show, by a single example, the serious errors committed, it will suffice to mention that Henry Marion Howe is not considered one of the leading students of metallurgy. Had the names been also classified under the various departments of study it would have added much to the value and interest of the book.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

814,728. CONTINUOUS STEEL-BILLET-CASTING MACHINE. — Oscar Potter, Wilmington, Del. Filed September 26, 1904.

814,769. CUPOLA. — Fred N. Cline, Chicago, Ill. Filed October 24, 1904.

814,249. GAS-PRODUCER. — James H. Swindell, Pittsburg, Pa. Filed December 13, 1904.

814,506. FURNACE-CHARGING MECHANISM. — David Baker, Wayne, Pa., assignor to one half to Albrecht B. Neumann, Joliet, Ill. Filed November 1, 1904.

814,557. APPARATUS FOR THE TREATMENT OF ORE FOR THE MANUFACTURE OF IRON AND STEEL THEREFROM. — Montague Moore, Melbourne, and Thomas J. Heskett, Brunswick, Victoria, Australia. Filed August 15, 1904.

815,016. PROCESS OF SMELTING IRON ORE. — Paul L. T. Héroult, La Praz, France, assignor to Société Electro Métallurgique Francaise, Froges, Isère, France, a corporation of France. Filed June 14, 1905.

815,181. CASTING MECHANISM. — William T. Krause, Baltimore, Md., assignor of one third to David R. Steele and one third to Harry D. Harvey, Baltimore, Md. Filed April 12, 1905.

815,198. CONTINUOUS-HEATING FURNACE. — William R. Miller Pittsburg, Pa., assignor to Forter-Miller Engineering Company, Pittsburg, Pa., a corporation of Pennsylvania. Filed December 24, 1905.

815,293. APPARATUS FOR SMELTING IRON ORE. — Paul L. T. Héroult, La Praz, France, assignor to Société Electro Métallurgique Francaise, Froges, Isère, France, a corporation of France. Original application filed June 14, 1905.

815,419. PRODUCTION OF ARTICLES OF ALLOY OF IRON AND HYDROGEN AGGLOMERATED IN STRONG COHERENT BODIES. — Harleston C. Gesner, New York, N. Y., executrix of George W. Gesner, deceased. Filed July 7, 1905.

815,794. GAS-PRODUCER. — Alberto Cerasoli, Rome, Italy. Filed April 22, 1904.

815,913. GAS-PRODUCER. — Carleton Ellis, New York, N. Y., assignor to Combustion Utilities Company, New York, N. Y., a corporation of New York. Original application filed May 11, 1905.

815,915. HOT-BLAST APPARATUS. — Joseph Fallek, New York, N. Y. Filed July 10, 1905.

816,142. PROCESS OF MAKING IRON FROM THE ORE. — Robert H. Aiken, Winthrop Harbor, Ill. Filed June 1, 1903.

816,222. BLAST-FURNACE CHARGING APPARATUS. — John W. Dougherty, Steelton, Pa. Filed March 17, 1905.

816,389. SLAG CEMENT AND METHOD OF MAKING THE SAME. — Joseph A. Shinn, Pittsburg, Pa. Filed July 8, 1901.

816,491. MAGNETIC ORE-SEPARATOR. — Richard R. Moffatt, Brooklyn, N. Y., assignor to Imperial Ore Separator Company, a corporation of New York. Original application filed July 19, 1904.

GREAT BRITAIN

28,570 of 1904. CONTINUOUS STEEL PROCESS. — V. Defays, Brussels. In the manufacture of steel by the continuous process, arranging the furnace so that the charge can be temporarily removed to another receptacle where the slag is got rid of, and the metal then returned to the furnace together with another charge of pig and reagents.

123 of 1905. ELECTRIC WELDING. — Thomson Electric Welding Company, Lynn, Mass., U. S. A. Improvements in electric welding machines chiefly in connection with regulating the amount of pressure put on the metals being welded.

16,385 of 1905. SPECIAL STEEL. — R. A. Hadfield, Sheffield. A steel of high tenacity, high elastic limit, ductility and toughness, containing 0.44 per cent of carbon, 0.3 per cent of manganese, $3\frac{1}{2}$ per cent of nickel and 1.71 per cent of chromium.

28,019 of 1904. BRIQUETTING IRON ORE. — W. Shumaker, Osnabrück, Germany. For the purpose of binding fine iron ores into briquettes, mixing the ore with very finely divided quartz and lime and submitting the briquettes to steam pressure, the action of the steam on the intimately mixed powdered quartz and lime being to form the colloidal silicate of lime, which is an efficient binding material.

8,555 of 1905. BLAST-FURNACE LINING. — F. C. W. Timm, Hamburg. In order to preserve the linings of blast and other furnaces, the inventor introduces with the charge an easily removable lining.

13,690 of 1905. ELECTRIC FURNACE. — P. Girod, Paris. In electric furnaces, arranging the electrode in such a way that the current will pass through the longest path possible.

3,179 of 1905. STEEL PROCESS. — Société la Neo-Métallurgie, Paris. The manufacture in an electric furnace of a compound containing 40 to 70 per cent of manganese, 20 to 40 per cent of silicon and 5 to 20 per cent of aluminum, to be used in the refining of steel.

6,001 of 1905. ELECTRIC FURNACE. — T. S. Anderson, Sheffield. An electric smelting furnace, especially for use in producing steel direct from fine iron ores and iron sands.

9,522 of 1905. ELECTRIC FURNACE. — J. F. Bottomley and A. Paget, Newcastle-on-Tyne. In electric smelting furnaces, arrangements of the electrodes so as to distribute the heat more evenly.

13,626 of 1905. BESSEMER CONVERTING. — F. Gebauer and A.

Zeuzes, Berlin. An improved method of restraining the ebullition of a charge of molten iron in the steel converter.

17,123 of 1905. ALLOY. A. E. Hobson, New Haven, U. S. A. A new alloy to be used as a substitute for britannia metal, being lighter and tougher than the latter, consisting of 109 pounds of tin, 3 pounds of copper, 9 pounds of antimony and 3 ounces of manganese.

EBER B. WARD

NEW DEVELOPMENTS IN DRY BLAST*

By A. STEINBART

THOSE who are connected with blast-furnace plants have "without doubt taken much interest recently in the old problem of removing the moisture from the blast, which has lately had a practical demonstration for the first time at the Isabella furnaces of the Carnegie Steel Company. I say the old problem because, to my knowledge, as far back as 1884 patents were applied for for a dry-blast plant using refrigeration.

The moisture in the atmosphere which enters the blast is principally in the shape of aqueous vapor. It is, on the average, higher in summer than in winter. In the months of July and August the moisture per cubic foot contained in the atmosphere varies from 4 to 9 grains and in January and February from 1 to 6 grains. These changes from one extreme to the other take place in a few hours sometimes, and cannot be predicted with better certainty than the weather.

In addition to the moisture, steam enters the blast from leaks in the engine house and from the exhaust of engines and steam formed by evaporation of water incident to the operation of the furnace, so that the blast frequently contains as much as 12 grains of moisture per cubic foot.

Upon coming in contact with the incandescent coke in the hearth of the furnace, the moisture is decomposed into oxygen and hydrogen, absorbing thereby 0.82 B. T. U. per grain of moisture decomposed. A sudden increase of moisture in the blast is always accompanied by a chilling of the hearth, an increase of sulphur and a decrease of silicon in the iron produced.

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* " Iron Trade Review," March 15, 1906. Paper to be read before the Technische Verein, Pittsburg, March 15, 1906.

Considering the foregoing, it looks strange that there was not long ago an attempt made to desiccate the blast, but there was another way of looking at the problem.

Roughly speaking, the moisture in the atmosphere amounts to 5 grains per cubic foot on an average over the whole year. There are about 60 cubic feet of wind used per pound of coke consumed in the furnace, so that 60 × 5, or 300, grains of moisture are blown into the furnace with the blast, per pound of coke consumed. One pound of coke, if burnt to CO_2, develops 12,600 B. T. U., and, if burnt to CO, it develops 3,800 B. T. U. Three hundred grains of moisture absorb 300 × 0.82, or 246 B. T. U. One third of the coke is burnt in the furnace to CO_2 and two thirds to CO; therefore, one pound of coke develops one third × 12,600 + two thirds × 3,800,

$$= 4,200 + 2,530.$$
$$= 6,730 \text{ B. T. U.}$$

The saving in coke which could be effected by removing the moisture appears, therefore, to be 246 ÷ 6,730 = 3.7 per cent on the average for the whole year. If coke costs three dollars per ton and one ton of coke is used per ton of iron, this would amount to 300 × 0.037, or 11.1 cents per ton, which, in view of the expensive and complicated plant necessary, hardly seemed a sufficient saving to warrant the experiment.

About eighteen months ago, however, Mr. James Gayley published results which he had obtained by passing the blast of one of the Isabella furnaces, before it entered the blowing tubs, through a chamber which contained 90,000 feet of pipe maintained at a temperature below 32 degrees. The moisture in the blast was reduced to below two grains per cubic foot. A saving of nearly 20 per cent in coke was effected.

Everybody, even Mr. Gayley, was surprised at the results, and his claims were attacked as extravagant. Those of you who are interested can find a compilation of criticisms in " Stahl und Eisen," in the December number of 1904 and the early numbers of 1905.

Mr. Gayley applied for a patent in which he claimed " the method of subjecting the ore with carbonaceous fuel to a blast of dried air, the burden of fuel being less than the normal burden by an amount materially greater than that which would be required to dissipate the eliminated moisture."

At the eighty-eighth meeting of the American Institute of Mining Engineers, Mr. J. E. Johnson explained the unexpected saving by pointing out that there is an amount of heat necessary in the melting zone for melting, etc., and that this amount of heat has to be furnished at a temperature above that at which the stock melts in the furnace. He called the melting tempera- ture of the stock the " critical temperature," about 2700 degrees. The amount of heat present above the " critical temperature" he called the " available heat." The available heat divided by the pounds of iron made gives the " available heat per pound of iron." The total available heat can be increased by removal of the moisture or by higher blast temperature, and more iron can be melted with the same amount of coke gasified by the blast.

I will now explain Mr. Johnson's theory graphically, and give in addition my reasons why there is in a dry-blast furnace less heat necessary per pound iron made, for reactions taking place below the critical temperature. For otherwise the stock would enter into the hearth very soon so cold that the available heat would have to be used for heating the stock instead of for melting.

In Fig. 1, area ABCD represents the heat units generated in the hearth and introduced by the blast in one minute. The base of the rectangular area contains as many units of length as there are heat units required to heat the blast entering the furnace in one minute through 1 degree; that is, 710; so that the height of the area measured by the same units of length represents the temperature to which the blast is heated by the amount of heat represented in the area. The area ABCD is composed of the heat generated by 40,000 cubic feet of blast in burning carbon to CO, *i. e.*, 2,340,000 B. T. U., represented by area LMCD, plus the heat in the blast due to its temperature of 800 degrees (730 degrees above atmospheric temperature), *i. e.*, 520,000 B. T. U., represented by the area EFML, minus the heat absorbed by the decomposition of 6 grains of moisture per cubic foot blast, *i. e.*, 200,000 B. T. U., represented by the area EFBA; so that the total heat supplied to the furnace is 2,660,000 B. T. U. per minute, represented by area ABCD.

The available heat ABGH is 790,000 B. T. U. If 750 pounds of iron are made in one minute, one pound of iron requires
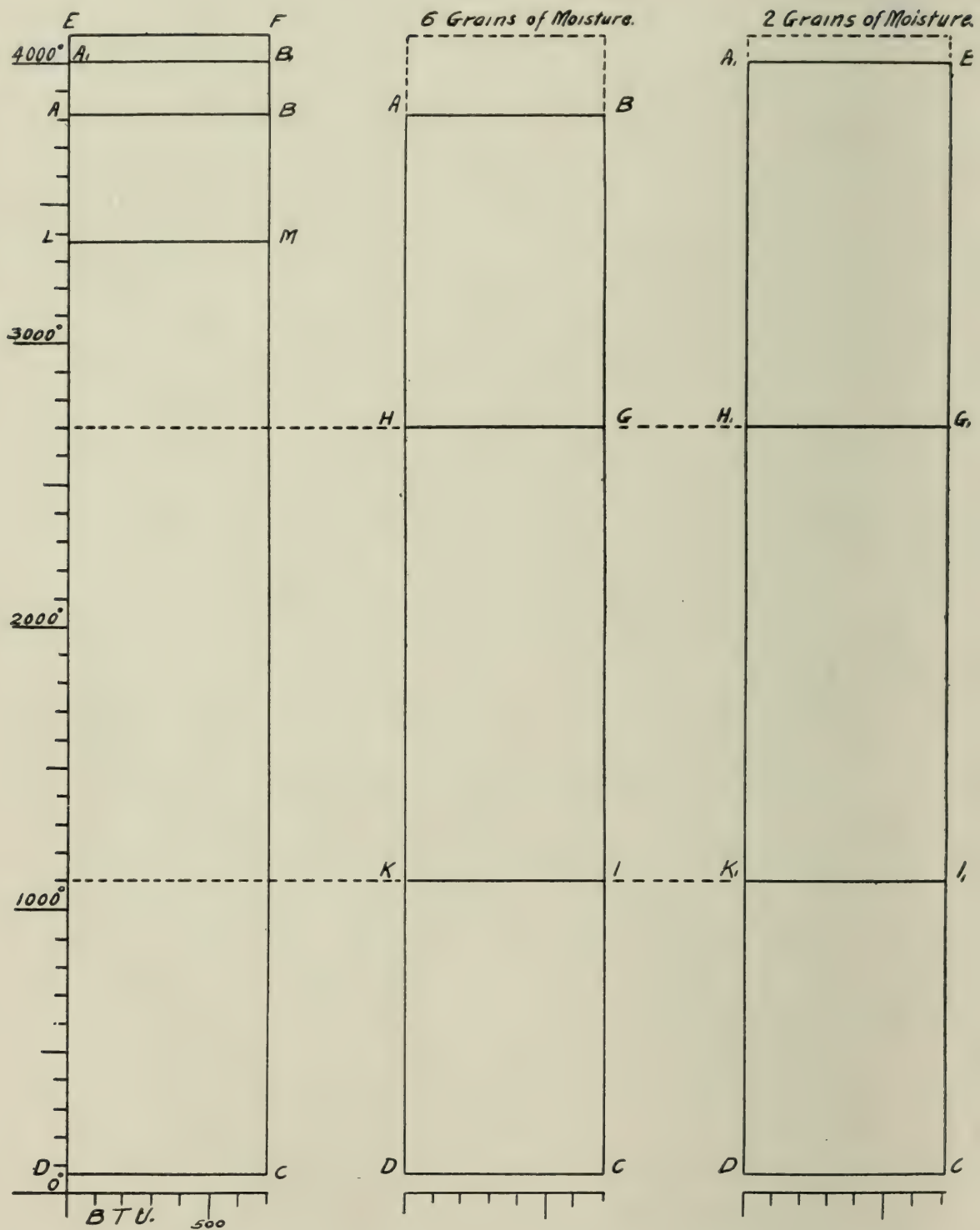
FIG. 1. Graphic Explanation of Johnson's Theory

790,000 ÷ 750 = 1,053 B. T. U. of "available heat" above 2700 degrees.

If the moisture is decreased from 6 grains to 2 grains, the total available heat is increased to 790,000 + (200,000 × 4–6) = 923,333 B. T. U., represented by area $A_1B_1G_1H_1$, and with this heat there can be melted 923,333 ÷ 1,053 = 877 pounds of iron, an increase of 17 per cent, equivalent to a saving of $14\frac{1}{2}$ per cent of coke gasified by the oxygen from the blast.

The heat of the gases traveling upward from the melting zone is used for heating the stock to the melting temperature, for decomposing the limestone into lime and carbon dioxide (which occurs at 1600 degrees), for reducing the ore and for evaporating moisture in the stock and heating the same to the temperature at which the gases leave the furnace.

The reduction of iron oxides is effected in the blast furnace either by carbon:

$$Fe_2O_3 + 3C = Fe_2 + 3CO,$$

or by carbon monoxide:

$$Fe_2O_3 + 3CO = Fe_2 + 3CO_2.$$
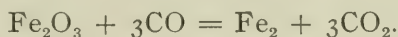
The reduction through carbon commences slowly at about 800 degrees and progresses more and more rapidly as the temperature increases up to a white heat.

The reduction through carbon monoxide commences at a temperature of 500 degrees and is most active around 1000 degrees. At higher temperatures the affinity of the carbon monoxide for oxygen decreases gradually and is lessened by dilution of the carbon monoxide with the carbon dioxide formed by the reaction. At temperatures above 1100 degrees, for instance, gas containing more than three volumes of carbon dioxide to two volumes of carbon monoxide acts even oxidizing towards iron and the same is the case with only one volume of carbon dioxide to two volumes of carbon monoxide if the temperature is above 1500 degrees. We may, therefore, assume that the temperature of the gas must be lowered to nearly 1100 degrees to allow reduction through carbon monoxide to such an extent that a large percentage of carbon monoxide is oxidized to carbon dioxide.

Reduction through carbon consumes heat; for 1 pound of

oxygen separated from the iron and combined with carbon, 4,300 B. T. U. are consumed in reducing Fe_2O_3 to Fe.

Reduction through carbon monoxide does not consume heat; for 1 pound of oxygen separated from the iron and combined with carbon monoxide, no B. T. U. are consumed in reducing Fe_2O_3 to Fe.

It follows that all the heat rising from the melting zone available over 1000 degrees which cannot be consumed by the heating of stock and decomposition of limestone must be spent in reduction of ore through carbon. The other part of the ore is reduced by carbon monoxide without drain on the quantity of heat emerging from the hearth. Equal amounts of heat, HGIK and $H_1G_1I_1K_1$, are left above 1100 degrees after subtracting the available heat from the total heat in the wet-blast and in the dry-blast furnace. There is, however, more stock heated from 1100 degrees to 2700 degrees and more limestone decomposed per minute in the dry-blast furnace. A larger quantity of heat is, therefore, abstracted between 1100 and 2700 degrees, and in addition to a saving of $14\frac{1}{2}$ per cent of coke gasified by blast, a saving of more than $14\frac{1}{2}$ per cent of coke gasified by the oxygen of the ore is obtained.

But will this increase of reduction through CO occur to supplement lessened reduction through carbon? If it does not occur the quantity of unreduced oxides travels into a hotter zone where it is reduced by carbon and thereby cools this zone. This continues till the heat has receded sufficiently towards the hearth to give a longer zone for reduction through carbon monoxide. The sketch Fig. 2 illustrates this: Curve *a* shows the heat as it will likely be at the different levels in the furnace with wet blast and curve *b* with dry blast. The curves *a* and *b* indicate the respective lengths of the zone where reduction prevails through carbon monoxide. In this zone the stock remains practically at the same temperature, for a long time in every case, but it remains for a longer time if less iron is reduced by carbon.

As the saving of coke by diminished gasification of coke through blast is $14\frac{1}{2}$ per cent and by diminished gasification through oxides is more than $14\frac{1}{2}$ per cent for 4 grains of moisture, we must expect at least a saving of $3\frac{1}{2}$ per cent for each grain of moisture removed from the blast per cubic foot.
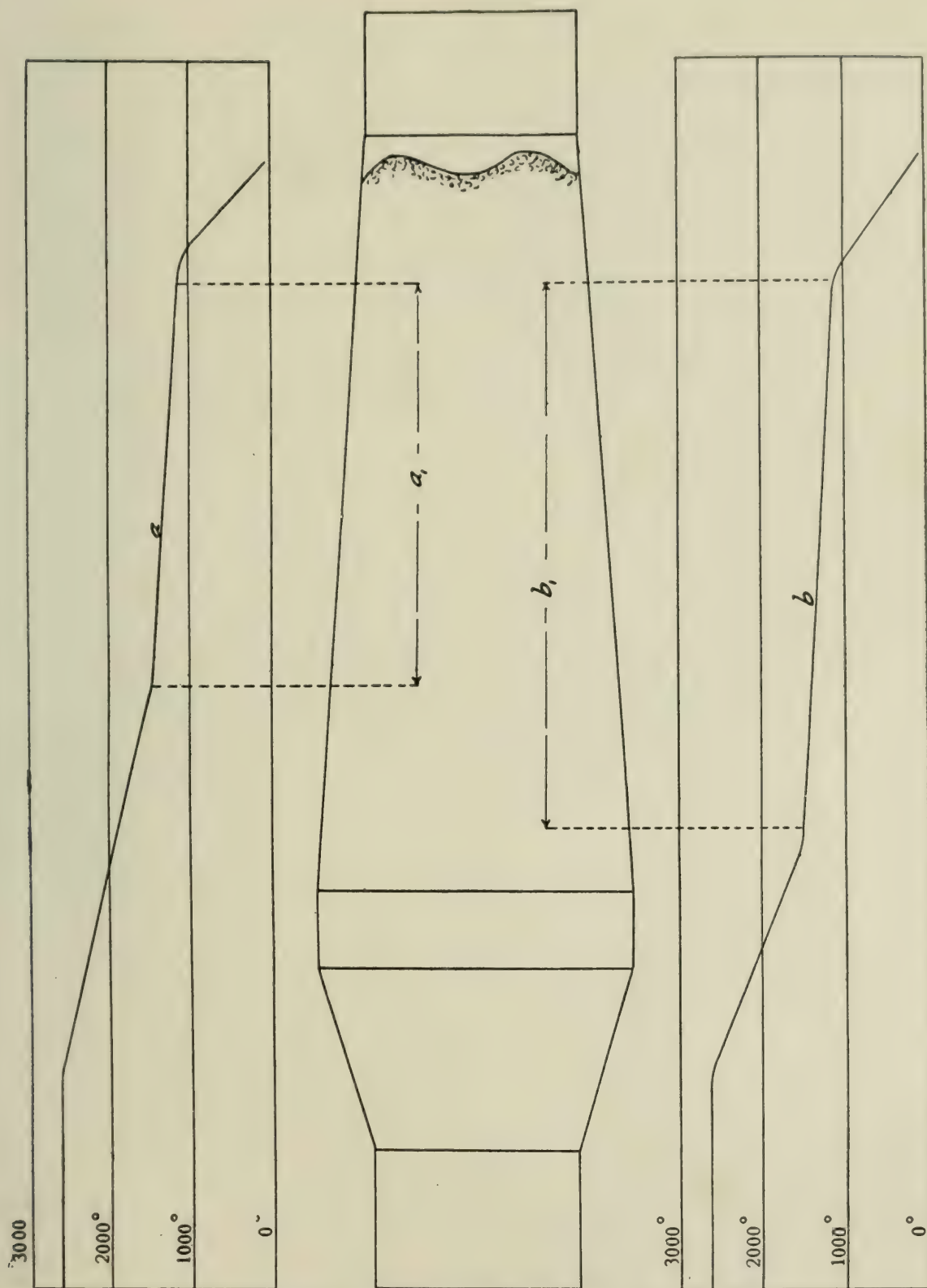
FIG. 2.—CURVES OF HEAT WITH WET AND DRY BLAST.

Now you see that the removal of the moisture must effect a large saving in fuel in the furnace, especially when we consider that we otherwise have to burden the furnace for the highest amount of moisture likely to occur in the season, though it may only last a few hours at one time. But this saving is at the expense of the calorific value of the blast-furnace gas.

The heat energy brought into the furnace by the coke and blast cannot be destroyed and must appear, therefore, again in some form. At the wet-blast as well as at the dry-blast furnace it appears again in the following forms:

(1) Heat in the iron; (2) heat in the cinder; (3) heat radiated from walls and given to the cooling water; (4) heat which becomes latent by chemical reactions; for instance, heat absorbed by splitting of the ore into iron and oxygen, or heat absorbed by splitting limestone into lime and carbon dioxide; (5) heat contained in the gas at high temperature; (6) heat contained in the gas as combustible constituents — for instance, carbon monoxide, hydrogen and marsh gas.

Heat in iron and cinder will remain the same per ton of iron irrespective of the coke consumed and irrespective if dry or wet blast is used as long as the same kind of iron is produced; except that the quantity of heat in the cinder will be slightly increased by increase of cinder through ashes and flux of additional coke.

Heat loss through cooling water and radiation will be inversely proportional to the number of tons produced in a unit of time and will be a little smaller in the dry-blast furnace, if the same has a higher production.

The heat which becomes latent through chemical reactions also remains substantially the same per ton iron. It will be slightly larger in the case of wet blast, as heat is used to split into carbon dioxide and lime 100 pounds of limestone for fluxing and 400 pounds additional coke per ton.

Therefore, it is evident that a constant amount of heat is used for smelting the iron, itemized under heads 1 to 4, and that any surplus of heat going into the hearth by larger coke consumption appears again in the gas and can be utilized in the stoves and for generating steam.

At works where there is use for more steam than can be generated from blast-furnace gas the saving of 400 pounds of

coke per ton of iron in the furnace is offset by an expenditure of 400 pounds of coal which has to be burnt under the boilers to furnish steam.

If the price of coke is $3.00 per ton and that of coal $2.00, 400 pounds of coke will cost 54 cents and 400 pounds of coal 36 cents, a difference of 18 cents per ton of iron. The cost of the dry-blast plant at Isabella furnaces per ton of iron made is 14 cents, so that we have a saving of only four cents per ton for blast furnaces and steel works as a whole.

The variable and high amount of moisture in the blast can be reduced, however, to a small and slowly varying amount by a method which I have devised and which only costs two cents per ton. The blast is cooled while under the pressure from the blowing engines by the bosh water.

The process is made possible by the fact that the moisture which may be contained in a space as vapor depends solely upon its temperature and not upon the presence or pressure of air in the space.

One cubic foot of space at 70 degrees, for instance, cannot contain more than 8 grains of water vapor; one cubic foot at 50 degrees not more than 4 grains and one cubic foot at 32 degrees not more than 2 grains. If two cubic feet of air at 70 degrees, containing 8 grains each or a total of 16 grains, are subjected to a pressure of 15 pounds per square inch and compressed into the space of 1 cubic foot and the temperature is maintained at 70 degrees, 8 grains must condense and can be removed. If the space is cooled to 50 degrees, 4 more grains must condense and can be removed; so that there are only 4 grains left in the original 2 cubic feet of air, or 2 grains in each.

The average pressure blown is 15 pounds. By cooling under 15 pounds' blast pressure, it is therefore possible to keep the moisture of the blast down to one half of what it would be if it was saturated at the temperature of the cooling water, and we may, therefore, employ water at natural temperature for cooling.

Monongahela River water has in summer a temperature of 70 degrees and in winter of 35 degrees, so that the moisture can be kept down in summer by its use to 4 grains and in winter to $1\frac{1}{2}$ grains. The moisture will vary slowly between these two extremes, as shown by curve B in Fig. 3.
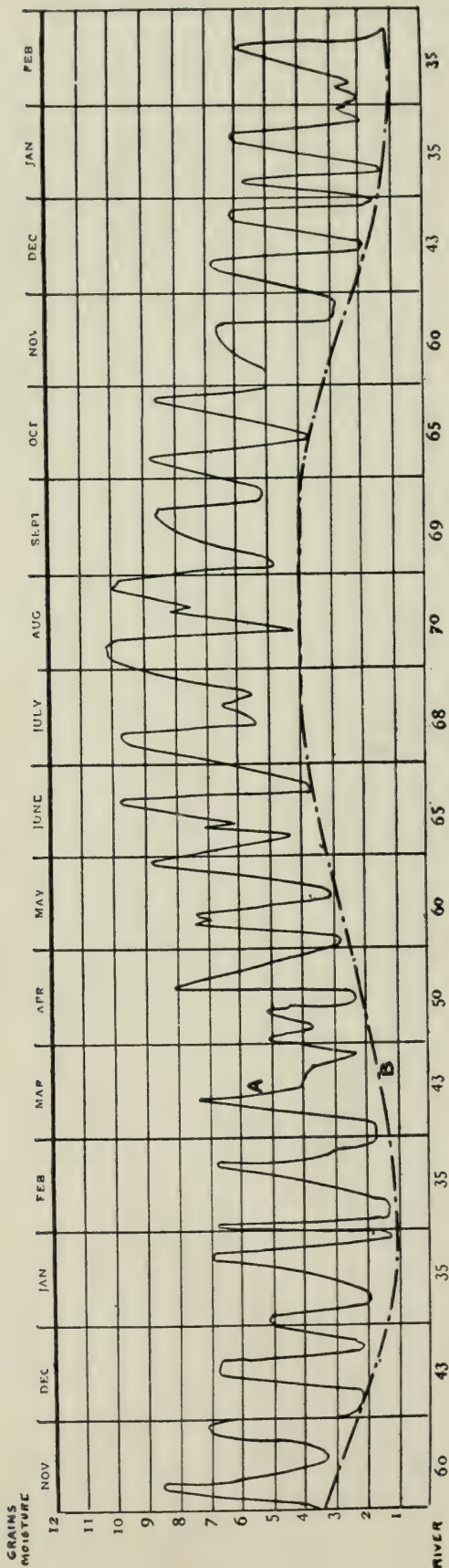
FIG 3.   Approximate Conditions in Monongahela Valley.

Curve A shows fluctuating moisture in blast at engine.   Curve B shows steady moisture obtained by use of Monongahela water.

The apparatus which I propose consists of a vertical cylindrical vessel of sheet iron, 60 feet high and 12 feet in diameter. It is closed at both ends and contains 4 horizontal tube sheets. The first and second, and the third and fourth tube sheets are 22 feet apart. The first tube sheet is connected with the bottom plate of the vessel by a central tube $3\frac{1}{2}$ feet in diameter. The second tube sheet with the third in the same manner and also the fourth tube sheet with the top of the vessel. The first and last tubes are connected by six T braces with the middle tube. The tube sheets are braced each with 12 I-beams.

A set of 1,000 boiler tubes $2\frac{1}{4}$ inches diameter connects the fourth and third tube sheets and a set of 1,000 boiler tubes of two inches diameter connects the second and first tube sheets. The tubes are $22\frac{1}{2}$ feet long and project 5 inches below the lower tube sheet.

The blast from the blowing engines enters at the top above the fourth tube sheet, passes through the two sets of boiler tubes successively and then leaves the apparatus at the bottom for the stoves. The water enters the apparatus at the bottom, cools the outside of the boiler tubes traveling in the opposite direction to that of the blast. It leaves the apparatus at the dome at the top to go from there to the bosh of the furnace.

The tubes in each set are arranged in 12 sections and a tray is hung under each section. Into the bottom of each tray short nipples are rolled in such a way that a nipple projects 4 inches into each boiler tube. The nipples in the trays of the upper set of tubes are $1\frac{3}{4}$ inches diameter and those under the lower set of tubes are $1\frac{1}{2}$ inches diameter. The moisture condenses on the inside of the tubes and runs down on the walls into the trays through the annular spaces between the nipples and the tubes.

Each tray is provided with an overflow tube which leads off the water of condensation. The water in the tray seals the annular space between the nipple and the tube so that the blast is forced to pass through the nipple without interfering with the collection of the condensed moisture.

The apparatus can be easily cleaned by washing out with a hose at times when the moisture in the atmosphere is low and no reserve is required. The boiler tubes can be removed after removing the plates in the top wall. The lower tubes can be passed through the upper ones.

The first cost of the apparatus for a 400-ton furnace is near $20,000; the cost of maintenance is low because there are no moving parts. The cost of operating is almost *nil*, as no attendance and no power is required.

In conclusion I come back once more to Fig. 3; curve A shows you to what degree the moisture varies in the different seasons. The temperature of the river water is given for each month at the bottom. Curve B shows how low and how regular the moisture may be kept by this simple apparatus, with natural water.

OPEN-HEARTH STEEL CASTINGS.* — V

By W. M. CARR

(Continued from page 394)

BASIC PRACTICE

THE problem of charging into a basic open-hearth furnace phosphoritic and otherwise impure materials, converting the same into good castings, offers many interesting features. To get satisfactory and uniform results, certain conditions require close attention and niceties of adjustment. When with a suitably lined basic hearth and the proper melting stock it is possible to begin with a high initial phosphorus and sulphur content and end with an almost complete removal of them, it is clear that the chemical history of the manipulations in conversion is more varied than that of an acid heat. As already stated, 95 per cent of the phosphorus and 60 per cent to 75 per cent of the sulphur can be eliminated in a basic bottom; there is then offered an opportunity to produce a class of output with a very low composition. Concerning the other constituents the conditions in regard to their removal during conversion and their presence in finished product are practically the same as in acid castings.

Given, then, a basic bottom and melting stock, the changes in a heat will be considered. The function of the basic bottom is only a refractory one and the material entering into it plays no part in the direct purification and conversion of stock. The calcerous slag is the active agent and the bottom must be of such material that the action of such a slag will have the least possible cutting effect. To minimize that effect, the best results will be obtained with a magnesite lining prepared as previously described. Limestone or calcium carbonate forming the slag and classified as a " base " will not flux with magnesite, also a " base." That is, an admixture of two or more bases will successfully resist high temperature or those common to steel melting; but a combination of an acid (silica, etc.) and a base (lime or magnesite, etc.) will, at similar ranges of temperature, readily fuse. Hence the metallurgical necessity of the hearth lining

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* "The Iron Trade Review," May 10, 1906.

being of a similar character chemically to that of the slag which may be formed in open-hearth melting.

Silica being greedy for any base and always ready to fuse in the presence of a base, the life of a basic hearth will be subject to its influence; therefore, it is important that the substance be allowed to enter the charge only in the smallest amounts possible. Through the charge it will be carried in as silicon (subsequently changed to silica) and sand adhering to the stock. With pig iron cast in chills, the amount of sand from that source will be practically *nil*. Defective castings charged directly from the molding floor may have more or less sand on them, and unless they are carefully cleaned to free them from burnt cores, etc., there will be danger of undue hearth scorification both on slag line and bottom, causing an increased use of refractories for patching.

Theoretically silica or silicon should be absent in basic stock. Practically it is not free from either, but the condition is none the less subject to control. Therefore, in selecting pig iron for basic melting the maximum percentage of silicon is given as 1 per cent. The amounts of that element in the various kinds of steel scrap are so low that the figures are negligible. Assuming the total charge to be equal parts of pig iron and steel scrap the initial silicon carried in by stock will average about 0.5 per cent. It is good practice to keep in the neighborhood of that figure, but a slight variation or increase will not be a serious objection. If there should be on hand some " off basic pig iron " that is high in silicon (over 1 per cent), or high in sulphur (over 0.05 per cent), a small quantity can be charged at the rate of about 1 per cent of the charge and will have but a very slight effect upon the desired initial composition.

In regard to sulphur and its position in the composition of the charge, it does not seem necessary to be very rigid as to how much can be considered dangerous. Actually, standard basic pig iron, while rated at 0.05 per cent maximum, carries more than that because of the generally accepted method of analysis giving uniformly low results. Were a more tedious method and a more accurate one employed, the figures on sulphur would generally be nearer 0.07 per cent than the standard stock requirements; hence the amount of sulphur actually going into a charge is really higher than shown by the individual analyses of the pig irons

forming part of it. The same differences between the apparent analyses and actual content of sulphur holds true on various grades of pig iron until very low amounts are reached. In the light of recent practice, the influence of sulphur in finished product is not regarded as harmful as it once was. There is, therefore, no good reason to place a strict limit on how much shall go into a charge. On an average the total amount will rarely go above 0.04 per cent. Rail scrap frequently carries 0.07 per cent and over. The pig iron will range from 0.01 to 0.05 per cent, and with many kinds of steel scrap to select from, ranging from 0.02 per cent and higher, it will not be difficult to keep the initial sulphur at or about the average stated if so desired. In the writer's experience there was a time when it was considered bad practice to have the initial sulphur exceed 0.03 per cent, and the aim was to get lower. (At this point the question as to the influence of sulphur will not be considered, but will be deferred to a subsequent section.) With a normal basic slag and proper conditions, much higher ranges of initial sulphur can be safely handled. There will be almost complete elimination in conversion, so that specification for finished product can be kept within easy reach, even with an initial sulphur of 0.07 per cent.

Concerning phosphorus and keeping in thought the ulterior limit in the analysis of finished product, it is as well not to make the entire pig iron charge all high phosphorus material. While the figures on standard basic pig iron are 1 per cent and were drawn for ingot practice, for castings it is better to have at least two kinds of basic pig, of which one may be low and one other standard. A brand carrying about 0.25 per cent of phosphorus or less is not difficult to procure. With a charge of mixed brands of pig iron and the usual varieties of scrap, it will be possible to keep the initial phosphorus of the charge low. During the progress of conversion and with a strong basic slag, there will be practically a total absorption of phosphorus by it from the bath. At the end of the heat, in recarburizing with ferro-silicon, etc., there will be a tendency on the part of the phosphorus to reenter the metal, depending in a great measure upon the amount of that element charged and the basicity of the slag. There is always some reabsorption, and it is greater with all high phosphorus pig than when it may be diluted with low phosphorus pig iron. Hence the need of mixing the pig iron in regard

to phosphorus content. Average practice will give a negligible reabsorption if the initial phosphorus is about 0.1 to 0.3 per cent.

In addition to the elements enumerated, there is always more or less manganese carried in with the stock. In basic melting it is useful in several ways. One function is to assist in maintaining a necessary fluidity of the slag, and it will exist in that body principally as an oxide resulting from the metal in the charge. It also aids in the removal of sulphur in the bath, and at some period during the melting unites with it, forming a readily fusible sulphide of manganese, which floats upwards, and either dissolves in the slag, or upon reaching the surface and becoming exposed to the flame action may be oxidized or volatilized. The action of manganese, however, is not quite clear, but from actual results there is no doubt that its influence in desulphurizing is quite potent. In that respect it operates in conjunction with the CaO (lime) furnished by the limestone, which is also an active desulphurizer. It has been observed that a moderately high initial manganese assists in washing the bath of dissolved oxides always present in metal which has been subject to the impinging action of the flame before the period of liquation has been reached and the mass disappears below the slag. The deoxidizing effect will not begin until the mass has partially or entirely fused and is covered with a layer of slag. De-oxidizing will take place by the union of silicon and carbon with the oxygen, and whatever manganese may be present in excess of that which may unite with the sulphur will considerably augment the effect. The joint operation of the three elements will certainly give cleaner metal. With ordinary melting stock the average or ordinary melting stock or the average or initial manganese will be about 0.5 per cent, but if it is possible, by the use of a high manganese pig iron to raise that nearer 1 per cent, the results or deoxidizing effect will be more satisfactory. Or in the absence of that kind of melting stock, the deficiency can be made up with spiegeleisen, an alloy carrying 20 per cent of manganese, or a certain amount of manganese ore will be useful for the same purpose, if charged at the proper time, — before the first portion of metal. It is recommended, however, that the needed manganese be carried in by high manganese pig iron, because it is possible to get a better distribution of that element

than by adding a small quantity of the alloy mentioned to make up any deficiency. For that reason it is good practice, when purchasing melting stock, to have on hand pig iron carrying between 1.5 to 2.5 per cent manganese.

Since pig iron generally contains 2.5 to 3.5 per cent total carbon and with 50 pig iron and 50 per cent steel scrap the initial carbon of a charge will be from 1.5 to 2 per cent. Whether the carbon may be in the combined or graphitic form is not considered, because, when the pig iron is liquid, it is all in the former condition irrespective of the constitution before melting. It will be observed that there is a difference between acid and basic melting in regard to the percentage of pig iron in the charge. In the former there will be 15 per cent, but in the latter 50 per cent. The reason for the difference is due to the larger volume of slag formed in basic melting, which requires a considerable portion of the heat units to penetrate it to promote the necessary fluidity of the bath of metal below. As has been pointed out, the amount of carbon present largely controls the melting point of iron and steel, and with a high initial percentage of it in a charge of cold stock, it is possible to acquire liquation at a relatively low temperature. Were there a low initial carbon as in acid melting, there would be much trouble with viscosity of the bath, because of heat absorption in the heavy body of basic slag. With the bath melted at a high range of carbon, the necessary thermal conditions are comparatively easy to attain. A high carbon at melting, between 0.5 to 0.8 per cent, is considered good practice; further, it means a prolongation of that period in which deoxidization or clarifying of the bath occurs, whereas a lower carbon at melting would shorten that period, and at the same time there would be undesirable conditions likely to arise, such as low temperature of bath, and overoxidized metal, both tending to give bad results in product. Should a heat melt soft (low carbon) it can be " doctored " by adding cold pig iron, and the temperature raised by flame adjustments, but recourse to such treatment is always dubious as to the outcome.

The foregoing elements of the charge being adjusted in accordance with general practice, the next step will be to consider the slag composition, which is to play an important rôle in the conversion and purification of the bath. In contrast to acid melting, the slag will be one highly charged with lime, a substance

already shown to be objectionable in an acid hearth, but desirable in treating basic stock. The normal composition of a basic slag will not be reached until the stock has melted and the slag attained its maximum fluidity, which period occurs during the second stage of a heat that, for convenience, may be designated " metals melted." Taking as an average the analyses of twenty samples of slag selected from various normal heats in the second stage, the following can be considered the usual composition of a basic open-hearth slag.

	Per Cent
Silica	16.00
Ferrous oxide	22.00
Lime	40.00
Magnesia	8.50
Manganous oxide	8.50

The foregoing analyses can only be regarded as applying to the conditions of practice existing when they were made, and not as a rule to follow in all cases, but under general conditions they may serve as a guide. In order to form a basic slag there are several important conditions to take into account. First, enough lime must be added to combine with or neutralize the silica which will result from the oxidization of the silicon carried in by the metals and that carried in mechanically as sand; otherwise there would be a thin slag and an undue cutting of the hearth by the silica. Second, too much lime must be avoided, which would tend to form a thick, pasty slag that would cause trouble in tapping the furnace or bring about a heavy consumption of fluorspar to flux it.

There is a medium to be sought between basicity and fluidity, and at the same time the function of the slag in absorbing and retaining phosphorus must not be overlooked. The measure of the latter action mainly depends upon the amount of lime in excess of that united with the silica, lime in a basic slag being the active dephosphorizing agent. As to fluidity, that condition in addition to the influence of silica will depend upon the varying amounts of manganese in the stock which enters the slag as an oxide. Oxide of iron operates in the same manner and is always present independently of that added as iron ore. The iron oxide of the slag will result from the rusty coating on the stock and the impinging action of the flame during the first stages of a heat.

In general terms the higher the content of silica the greater the fluidity, but at the expense of dephosphorization and hearth. Fortunately the medium can be found because of the presence of iron and manganous oxide, since a law seems to exist in slag formations that fluidity or fusibility is controlled by the number of bases present. So, assisted by manganese oxide and iron oxide in the presence of lime and silica, desirable slag conditions in basic melting can be attained without much difficulty. In addition to the elements given in the slag analyses there may be small negligible quantities of alumina and alkalies. The amount of magnesia results mainly from hearth cutting. To forecast the exact amount of lime to be added solely on theoretical grounds is not easy, because the total available silica cannot be accurately determined owing to the uncertain quantity of sand adhering to the stock. Whatever silica may be available in the stock will require at least enough lime in the ratio of 1 to 3 to satisfy it. Also the purity of the limestone, generally used as a carrier for the necessary lime of the slag, must be taken into account, and any silica this may have will depreciate the available lime in the same degree. Therefore, the nearer a limestone approaches a pure carbonate of lime, the greater the efficiency. In actual practice the amount of limestone required to form a normal slag will vary between 7 and 15 per cent of the weight of the charge. With standard melting stock and a pure limestone it will be comparatively easy to get satisfactory adjustments. In the hands of a skillful operator, assisted by the chemist, the behavior of a heat can be followed at any desired stage, so that untoward conditions of purification will be within control. Agencies are constantly at work in slag formations following the laws of attractions and affinities which present problems of scientific interest. To solve their complexities would be a difficult task.

If an open-hearth furnace be regarded as a chemist's laboratory experiment on a large scale, and viewed from a chemist's standpoint, the delicacies of definite chemical reactions are not obliterated because of the very hugeness of a furnace. Whether the operation be conducted on a minute scale or on a larger one, definite laws are omnipresent. Could the operator bear in mind that he is handling tons of material with forces equally potent as in the chemist's ounces, he would stand in awe of them.

Careful, intelligent work, combined with practical experience, makes it possible to put basic practice in the same plane of efficiency as acid melting, notwithstanding prejudice to the contrary existing in some minds.

Having determined upon the amount of limestone to form the basic slag, the next step will be to consider the order of charging. With a basic hearth prepared as outlined in previous sections, the method of charging may be conducted as follows: First, the stone is spread over the bottom in as regular layers as possible, followed by the lighter sections of scrap, which should be more or less rusted; or, if not rusty, some iron ore may be added with it to make up the lack of oxide to assist in subsequent slag fusibility. Then, two thirds of the pig iron, distributed as evenly as possible, which may be followed by the remainder of the scrap. By this time the furnace will be well filled with bulky stock, and it may be necessary to allow the flame to partly melt it, thus forming room for the final addition of pig iron. The serious part of melting now begins, and at this stage the finished product in regard to quality will be greatly influenced by the manner in which the exposed stock may be subjected to flame action. There will be a desire on the part of the operator to get the heat out of the furnace in record time, and with speed in mind the temptation to use a sharp, hot flame will be strong. On the other hand, a soft, mellow flame will not melt as quickly as a sharp one, yet the character of the product will be better than under the first-named conditions. In one instance the bath will be highly charged, when melted, with dissolved oxides, and in the other instance less so. It is not possible, under any conditions, to melt a mass of pig iron and steel scrap without some formation of oxides and their subsequent solution in the bath, so long as it remains uncovered by a protective layer of slag. Good practice requires that there be a dividing line between speed and slowness, a sharp flame and a soft one, and that object is a difficult one to reach. The quantitative expression of dissolved oxides cannot be stated, but their influence can be detected in varying degrees. That such conditions do exist is a fact, and the conclusion is based upon careful observations and research, the results pointing undoubtedly to the influence of the flame action, whether gas or liquid fluel may be used and also the amount of initial carbon present in the stock. Oreing during the

second stage or " metals melted " also may aggravate the evil. That it is an evil will be pointed out, and one not fully appreciated or understood. To it can be traced the non-success and consequent prejudice against basic melting, because, in some instances, it has been found in certain physical requirements that basic steel was not as good as acid steel for castings. In other words, expressing the difference between basic and acid steel in regard to certain physical properties, basic steel is more likely to carry dissolved oxides than acid, provided care has been taken to guard against their introduction or formation. Differences in chemical composition can only exist in the amount of sulphur and phosphorous for a given grade of product, and the said differences being too small to exert any great influence, no cause can be assigned other than the one mentioned in studying the contrasting physical properties of both classes of steel. The condition of overoxidization is not so liable to present itself with a gas flame, but even such a flame can be so adjusted as to abuse the stock. With an oil flame the danger is greater, because of the intense blow-pipe effect of the oil burner. In experienced hands, however, quality duly regarded, normally the oxidizing effect with any kind of fuel need not be excessive.

Under flame action in a fully-charged furnace, the stock will soon begin to melt, and it will be observed that the melting of the pig iron goes on quite rapidly, dripping to the hearth in small streams, while the steel scrap melts at a slower rate, and in melting, the liquid steel frequently scintillates or burns, forming either vapors or solid oxide. The dripping pig iron lessens that action more or less, by protecting the lower carbon steel stock. The melting proceeds gradually, and the mass decreases in bulk and passes below a layer of rapidly forming slag. At this time, however, the slag formation is not entirely complete, but will be found to consist mostly of silica and iron oxide with comparatively little lime, the temperature of the furnace at this point not being sufficiently high to thoroughly dissolve the lime still resting on the bottom of the furnace. The composition of the slag at this period is practically an acid one and results from the sand of the stock and the silicon of the metals, since it is one of the first elements to submit to oxidization. Samples taken from the first portions of melted metal have shown a high sulphur content, much higher than that carried in by the stock. The cause can

be attributed to the absorption of sulphur from the flame. During the first stage but little information can be ascertained as to the changes which may take place in the composition, because the mass is a conglomeration of pasty semi-liquid pig iron, steel and slag.

BRITTLENESS AND BLISTERS IN THIN STEEL SHEETS *

By EDWARD F. LAW, Assoc. R.S.M., London

THE occurrence of blisters in the thin steel sheets used in the manufacture of tin plates has from time to time attracted the attention of metallurgists, but so far no completely satisfactory explanation of the cause of these blisters has been advanced. During the discussion of a paper by Mr. C. H. Ridsdale,† in which the subject had been touched upon, Mr. Stead declared that in his opinion " the matter was wrapped up in mystery," and added that " the whole question of blisters in tin plates required more investigation." With this object in view, the author undertook an extended investigation into the causes which underlie the production of brittle and blistered tin plates, the results of which will be given as briefly as possible.

In his paper on the " Diseases of Steel," Mr. Ridsdale attributes blisters to two main causes, viz.:

1. Those due to pre-existing blowholes in the ingot or bar; and

2. Those due to other causes.

The latter he classifies under five heads:

(a) *Overheating* of the bar or sheet, causing development of blisters by permitting the growth of grain, and giving rise to larger laminæ and great tendency to separation. The laminæ can be distinguished under the microscope by their larger grain size.

(b) *Outsides* causing blisters due to oxidation.

(c) *Pickling only*. Abnormal treatment in the pickling bath.

(d) *Along line of roughness caused by streaks*.

(e) *Airing*, due to admission of air into the annealing box. These causes, however, may be regarded as exceptional,

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and do not explain the fact that some brands of steel have a far greater tendency to produce blisters than other brands, when the two are treated in precisely the same way and, in fact, worked together.

In the first place, a careful search was made for any sheets showing a tendency to brittleness in any stage of the manufacture, from the rough black plate to the finished tin plate, and these were all examined and compared with tough sheets. It was soon found that blistered sheets were usually, but not invariably, brittle, while, on the other hand, many brittle sheets showed no signs of blisters. Heat treatment failed entirely to improve the sheets, and, moreover, a microscopical examination revealed no evidence of overheating or of abnormal treatment.

Evidently, then, the defect which gives rise to blistered sheets must be distinguished from that which gives rise to brittle sheets, although the two may, and often do, occur in the same sheet.

A microscopical examination of a large number of sheets showed that the brittle and blistered sheets were invariably of less pure steel than tough sheets, and an examination of the original steel from which the sheets had been rolled fully confirmed the results of the examination of the sheets. These steels showed marked segregation, and were invariably very impure, the impurities being sulphur, phosphorus and another constituent whose identity has not been definitely settled, but which the author believes to be oxide, and which, for the sake of simplicity, will be described as oxide. This impurity is always associated with blistered sheets.

In order to determine, as far as possible, the effect of the quality of the steel on the finished sheet, six samples of steel from various sources were each rolled out into twenty-four sheets, and worked together so that they might all receive the same treatment. The sheets were examined for blisters, and portions of the bars adjacent to those rolled were analyzed and examined microscopically. The table on next page shows the results of this experiment.

As regards the result of the chemical analyses, it will be noticed that samples 66, 68 and 70 are high in phosphorus, but apart from this there is nothing to show why one sample should

give better results than another. The microscope, however, reveals a very marked difference in the quality of the steels.

Sample	Description	Microscopical Examination	Good Sheets	Blistered	Analysis			
					C	S	P	Mn
65	Acid Bessemer	Clean	24	..	0.131	0.061	0.049	0.340
66	Acid Bessemer	Dirty	15	9	0.136	0.061	0.081	0.350
67	Acid Open-hearth	Very clean	24	..	0.166	0.056	0.075	0.360
68	Basic Bessemer	Very dirty	5	19	0.117	0.071	0.090	0.480
69	Basic Bessemer	Clean	24	..	0.132	0.069	0.034	0.385
70	Basic Bessemer	Very dirty	16	7	0.106	0.079	0.098	0.440

From these samples No. 70 was selected for further experiments, and the sheets rolled from it were tested by a close-fold test, which showed very variable results, as follows:

The seven blistered sheets seamed down with a very rough edge and broke off coming back.

Three sheets (8, 9 and 10) seamed down with a rough edge and broke off coming back.

Four sheets (11 to 14) seamed down with a smooth edge and were weak coming back.

Nine sheets (15 to 23) seamed down with a good edge and were very tough coming back.

Cuttings from each sheet were then analyzed, and the accompanying table shows the separate analyses, together with the mean of each group.

The principal point to be observed in these analyses is the low sulphur in the tough sheets — only 0.056, as against 0.08 in the brittle sheets. The manganese is correspondingly low (the sulphur existing as sulphide of manganese), while the phosphorus is only slightly lower than in the brittle sheets.

The question now arises, How do these impurities influence the quality of the sheet? and, in order to answer this question, it will be well to consider them separately, as they occur in the steel during the different stages of the manufacture of a tin plate.

Taking, first, the case of a steel containing large quantities of oxide, such, for example, as a steel produced from a somewhat overblown Bessemer charge: The chemical analysis of such a steel will fail to reveal anything abnormal, but a microscopical examination will at once reveal the presence of oxide.

Now, in the pickling bath, large volumes of hydrogen are evolved, and it is well known that hydrogen is capable of entering and passing through a thin sheet of steel. Further, nascent hydrogen is a powerful reducing agent, and this hydrogen, assisted by the high temperature of the pickling bath, reduces the oxide in the steel with the formation of water vapor. The volume of the molecule of water is, however, much greater than that of hydrogen, and therefore is incapable of passing out of the sheet.

Number of Sheet	Carbon Mean		Sulphur Mean		Phosph. Mean		Mn Mean	
1	0.070		0.077		0.074		0.400	
2	0.077		0.095		0.072		0.413	
3	0.080		0.080		0.073		0.410	
4	0.079	0.076	0.084	0.084	0.072	0.073	0.400	0.402
5	0.069		0.075		0.072		0.394	
6	0.074		0.090		0.077		0.393	
7	0.086		0.089		0.069		0.403	
8	0.077		0.087		0.075		0.403	
9	0.083	0.079	0.075	0.080	0.063	0.068	0.410	0.404
10	0.076		0.078		0.065		0.400	
11	0.073		0.090		0.071		0.413	
12	0.075		0.067		0.069		0.410	
13	0.075	0.073	0.084	0.081	0.070	0.070	0.390	0 401
14	0.071		0.082		0.071		0.393	
15	0.072		0.055		0.083		0.390	
16	0.070		0.049		0.050		0.386	
17	0.073		0.063		0.071		0.400	
18	0.070		0.043		0.061		0.390	
19	0.072	0.073	0.058	0.056	0.057	0.067	0.400	0.396
20	0.074		0.053		0.055		0.393	
21	0.071		0.051		0.064		0.396	
22	0.075		0.080		0.109		0.406	
23	0.076		0.053		0.056		0.400	

Moreover, the volume occupied by the water vapor is much greater than the volume occupied by the original oxide, and the internal pressure thus produced is sufficient to cause an incipient blister, which increases in size, owing to the expansion of the water vapor when the sheet is subsequently annealed. During the annealing, however, the reaction is reversed, for at a red heat water vapor is again decomposed, with the formation of oxide and liberation of hydrogen. The enormous pressure produced by the expansion of water is well known, and in the

pickling of hardened steel containing 0.8 per cent carbon the pressure is sometimes sufficient to cause complete fracture.

Sulphur and Phosphorus. — These impurities may be considered together, as they almost invariably occur together in the steel. It is well known that sulphur and phosphorus segre-
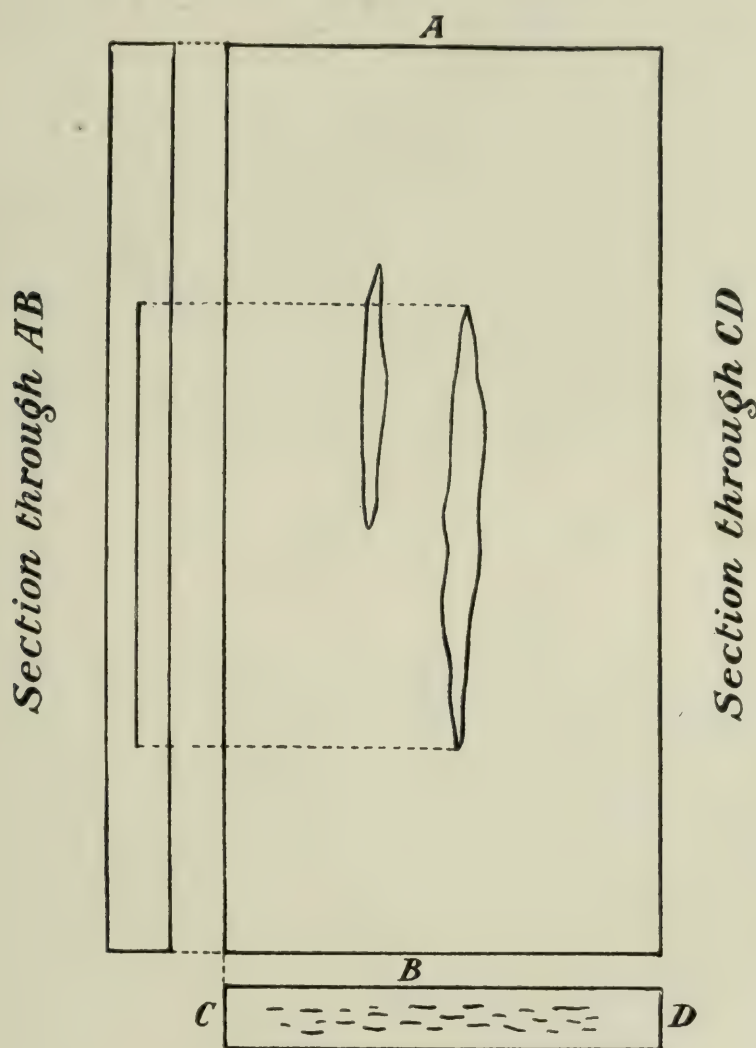

FIG. 1.

gate towards the center and top of an ingot, and it is interesting to follow the segregation as it occurs in the bar and in the finished plate. In the ingot these segregations occur more or less spherically, so that when the ingot is rolled into a bar they are flattened and much elongated, and appear as shown in the figure.
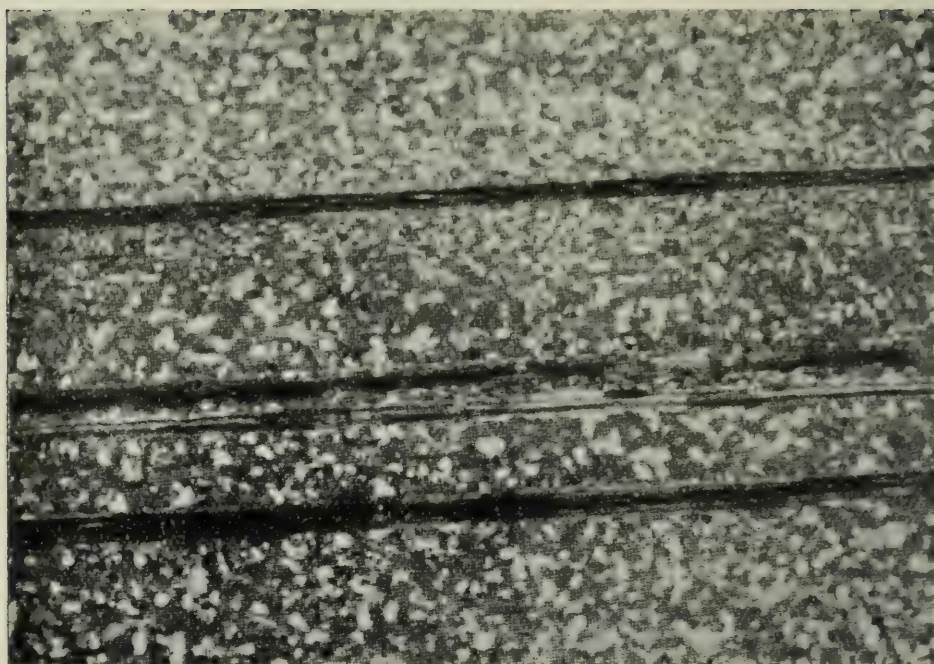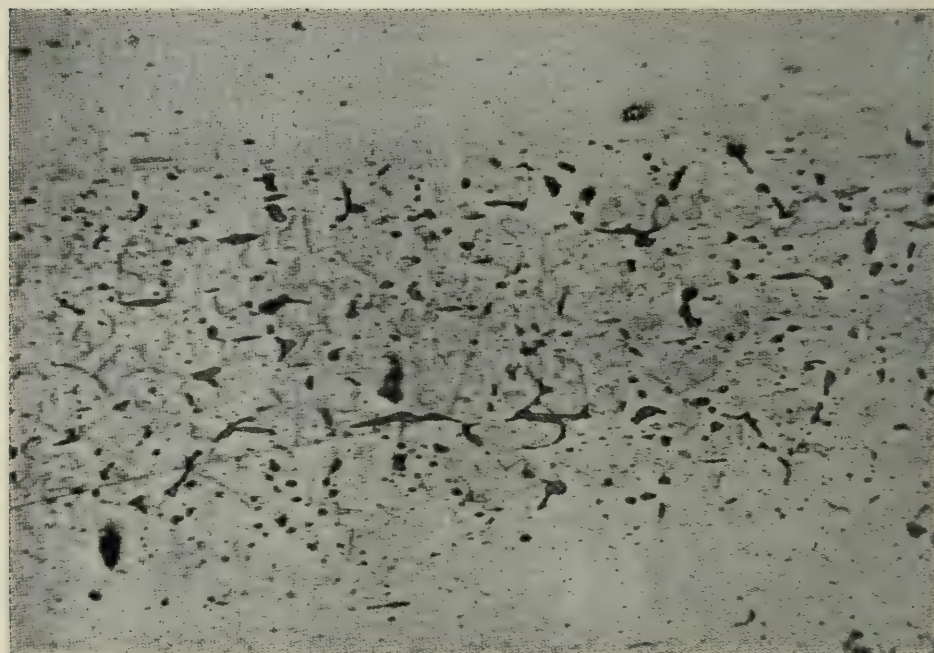
FIG. 2.	Magnified 10 diameters

FIG. 3.	Magnified 200 diameters

If a section of such a bar rich in sulphur and phosphorus is cut across and roughly polished, these segregated portions appear as bright lines, and are the well-known " ghosts " of the engineering workshop.   By taking thin shavings of these " ghosts " it can be proved that they are very high in sulphur and phosphorus, often containing five or six times the amount of these constituents shown in the ordinary analysis.   Even drillings taken along and across the bar will give very variable results.   An example of this was found in the case of a bar showing marked segregation in which drillings were taken through the bar and along the bar in the direction of rolling. These gave on analysis:

	Through the Bar	Along the Bar
Carbon.....................	0.117	0.120
Sulphur.....................	0.080	0.104
Phosphorus.................	0.068	0.087

The analysis only reveals the fact that the ghost is rich in sulphur and phosphorus; but the microscope enables us to see through the ghost, and the following photographs show the nature of these segregations.

Fig. 2 shows a section of the ghost lines as they appear when deeply etched with nitric acid.

Fig. 3, which is magnified two hundred times, shows the way in which the sulphur exists as manganese sulphide.   A section containing a ghost is at once seen in a polished section without etching by the regular band of manganese sulphide inclusions. The specimen shown in the photograph has been very slightly etched in order to show the position of the carbide patches in relation to the manganese sulphide inclusions.

Fig. 4 shows the same specimen, and at the same magnification, but more deeply etched.   It will be noticed that the ghost line has etched more readily than the surrounding metal owing to the high percentage of phosphorus in it.

Fig. 5 is a portion of the same sample, but magnified two thousand times, showing manganese sulphide and carbide rich in phosphorus.

Fig. 6 has been included here to show the influence of these ghosts on the ductility of the steel.   The bar has been cut with shears, and it will be noticed that the steel tends to fracture
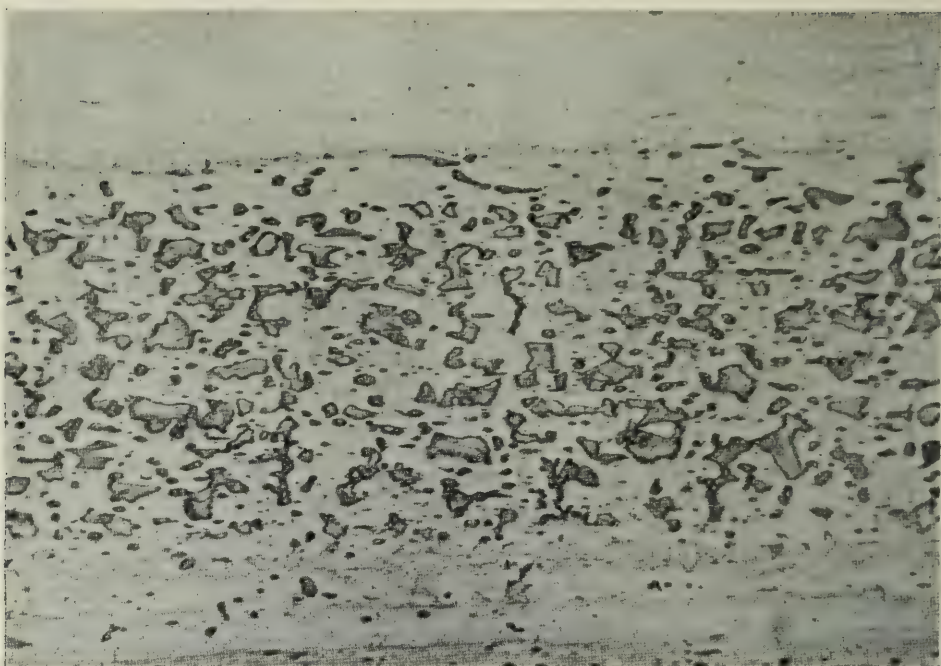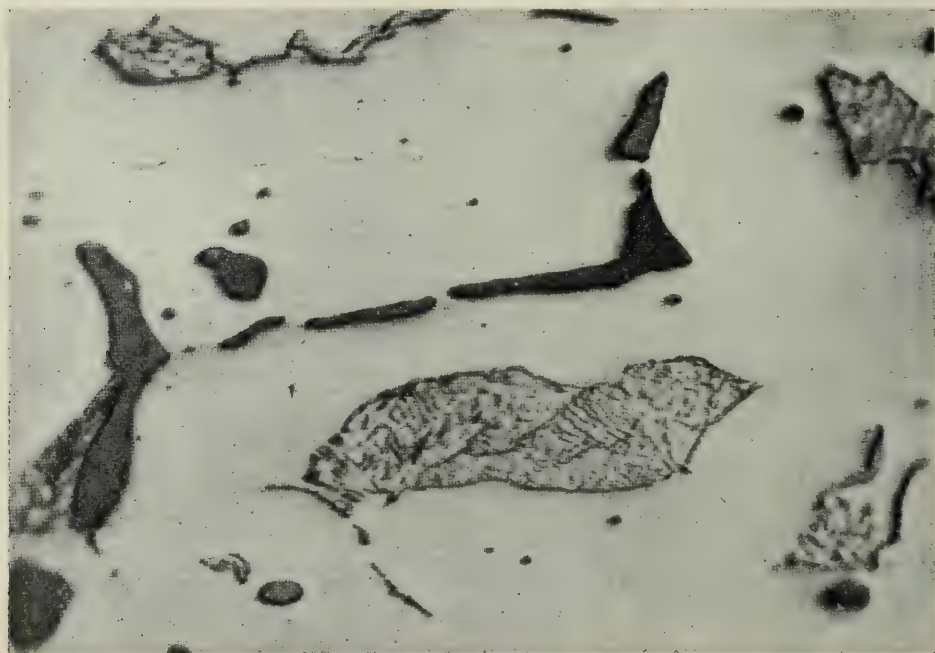
FIG. 4.   Magnified 200 diameters

FIG. 5.   Magnified 2,000 diameters

along the lines where the metal has been cut. Now in the thin sheet the same thing will happen, but in this case the area of the ghost lines is enormously increased owing to the extended influence of rolling, and even the manganese sulphide, which is usually considered harmless, becomes rolled out to such an extent that its influence in a thin sheet can no longer be regarded as negligible.

Fig. 7 shows the appearance of the manganese sulphide inclusions in the section of a sheet.

Evidently, then, a thin sheet, rolled from a bar showing ghosts, will consist of laminæ of ductile steel separated by laminæ of less ductile and highly phosphoric steel, together with laminæ of manganese sulphide. When such a sheet is subject to bending, the ductile material tends to slip over the less ductile material, and the sheet fractures, or is brittle. If the defect is due to this cause, the brittleness should not be uniform throughout the sheet, and as a matter of fact this is found to be the case. For example, a sheet selected at random and cut into thirteen strips gave the following results when each strip was tested in the usual way by noting the number of bends required to give a rough edge and finally to fracture:

No. of Sheet	No. of Bends	No. of Sheet	No. of Bends	No. of Sheet	No. of Bends	No. of Sheet	No. of Bends
1	19–20	5	16–17	9	13–14	13	14–15
2	17–18	6	16–17	10	14–15	...	....
3	16–17	7	16–17	11	12–13	...	....
4	16–17	8	13–14	12	14–15	...	....

In a single sheet there may thus be a comparatively wide range of ductility, so that a single close-fold test on a sheet is not merely an insufficient guarantee of the ductility of the remainder of the sheets in that batch, but is not even a trustworthy indication of the quality of the sheet itself.

The results of the investigation would seem to show that:

1. Oxidized steel will give rise to blistered sheets, and that this defect is more liable to occur with Bessemer than with open-hearth steel.

2. Steel high in sulphur and phosphorus will cause brittleness in sheets, especially if the sheets are rolled from large and slowly cooled ingots, in which the maximum of segregation has taken place.
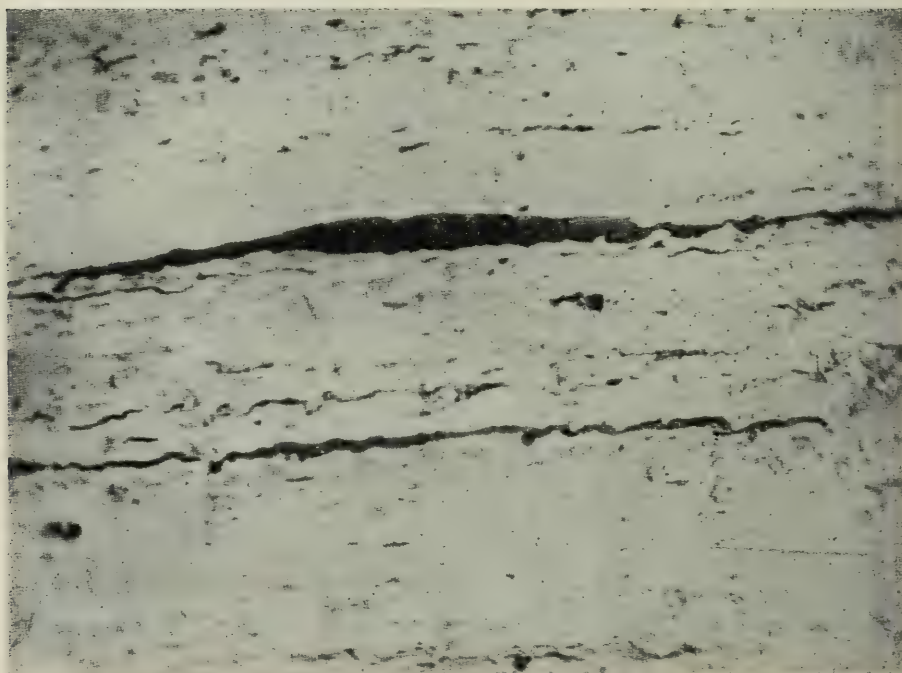
Fig. 6

Fig. 7

In conclusion, the author wishes to express his indebtedness to Messrs. Richard Thomas & Co., who have not only given him the benefit of their wide experience, but have also carried out experiments for him which it would have been impossible to imitate in a laboratory.

COMPRESSION OF STEEL INGOTS IN THE MOLD *

By A. J. CAPRON, M. Inst. Mech. E. (Sheffield)

THE subject of the fluid compression of steel has recently assumed such prominence that but little introduction is necessary. Its use up to the present has been chiefly confined to the higher qualities of steel and the largest sizes of ingots, but the system to be described is relatively very cheap, both in first cost and in working, and moreover a single press can deal equally well with a few ingots of moderate size or with a large number of smaller ingots, making the process applicable on a much more commercial and wider scale. The process consists in utilizing special forms of ingot molds, so constructed that pressure can be applied to the ingots in a horizontal press. The ingot molds are preferably placed in series, so as to reduce the power of the press required. It should be mentioned that both the various forms of molds used and also the press are the subjects of patents which have been taken out by Messrs. Robinson and Rodger of Sheffield, and constitute improvements on the American and English patents of Mr. John Illingworth, of New York. On this system a horizontal press was used, and means were provided for opening the molds after the casting of the ingots. These ingots were of small size, say about 80 pounds, and the method of pressing was to insert a plate or wedge between the opened mold and the still hot ingot. Upon the pressure being applied the mold was closed, and the ingot compressed to the extent of the thickness of the inserted plate. This mode of procedure was found to be inapplicable to ingots of any considerable weight, and the methods about to be described were devised and used up to the present with unvarying success. Mr. Illingworth is interested with Messrs. Robinson and Rodger in these new developments.

The construction of the ingot molds and of the press are

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* Iron and Steel Institute, May, 1906, meeting.

illustrated by the model, and also by Figs. 1 and 2. It will be seen that the ingot molds are placed inside the press, the steel being run into the molds in this position, so that they have not to be transported with the liquid steel in them, and the press practically forms the casting pit. The ingot molds are open at the bottom, and may each have a separate loose bottom plate, or may stand upon one common plate for bottom running.

In Fig. 1 the ingot molds are divided in the center, there being a loose packing piece of any convenient form and size on each side between the halves of the mold, or the entire sides of the molds may be made removable according to the purpose for which the ingots are intended. The steel is cast into all the molds simultaneously, either by means of a trough with a separate runner for each mold, or in groups by means of bottom running. Within a few minutes of the casting the ingots solidify on their surfaces, and shrink away from the molds, so that the packing pieces can be withdrawn with perfect safety, and the pressing can be commenced, just sufficient pressure being applied to follow up the contraction that is taking place. The pressure is continued, and gradually increased during solidification, until a final pressure of about 2 tons per square inch on the surface is reached, and this pressure is maintained for a short time, insuring absolute solidity in the ingot throughout.

Another construction of ingot mold is shown in Fig. 2. The sides are held in place by grooves in the cross plates, which are made deep enough to allow for the requisite compression. The press holds the molds in place during casting, and there being no packing pieces to remove, can at once follow up the contraction until the maximum pressure is reached.

The construction of the press which is adopted in this system is illustrated by the model and by Figs. 1 and 2, Fig. 1 illustrating a press of 8,000 tons, and Fig. 2 of 5,000 tons. The various parts are as follows:

A, A, Pressing Cylinders.
B, B, Pushback Cylinders.
C, C, Tension Bars.
D, D, Steel Straps (in tension).
E, E, Cast Iron Packing Blocks (in compression).

The length of the ingot molds being generally greater than their width, it is convenient to have two pressing cylinders, as shown.

8000 TONS HYD⁰ PRESS FOR FLUID COMPRESSION OF STEEL.
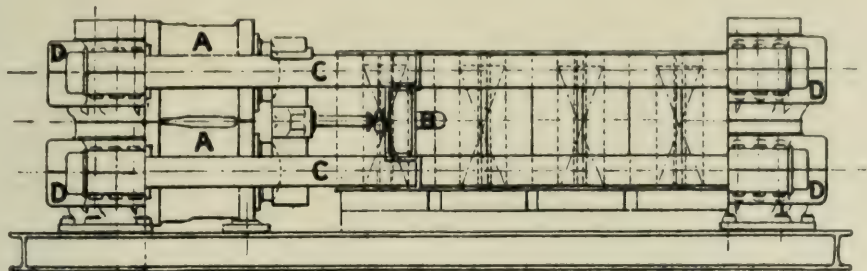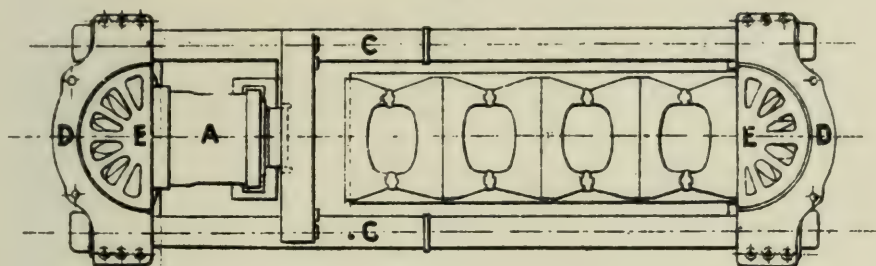## ·ROBINSON & RODGER'S PATENTS·

Fig 1.

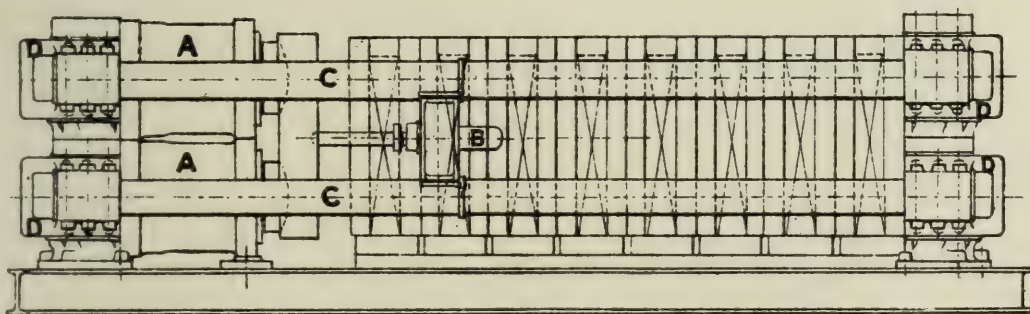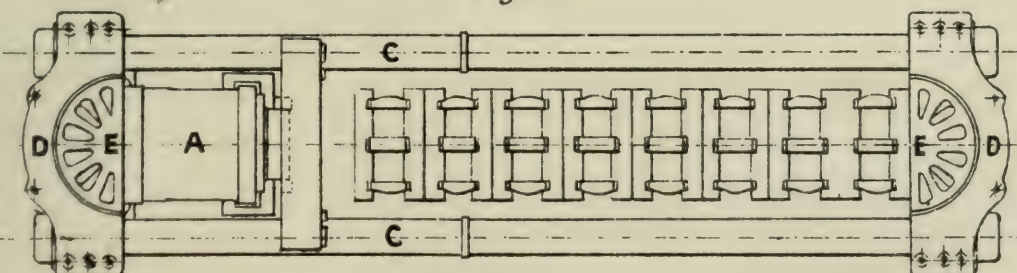# 5000 TONS HYD⁰ PRESS FOR FLUID COMPRESSION OF STEEL.

Fig 2.

one above the other, so as to distribute the pressure better on the molds. This halves the size of the pressing cylinders, and reduces the weight of the parts. The cylinders abut on the semicircular packing blocks and the strain is transmitted to the columns through the steel straps. These straps may be made in halves, as shown, in which case no nuts are required on the columns, but only plain solid collars. This construction of press has also been patented, the advantages being simplicity and cheapness compared with the usual design of press. It is also an extremely convenient form of press for erection, and the weight of the various component parts is extremely moderate, even for presses of very great power. The rams are made hollow and fitted with spherical-ended thrust-rods, so as to avoid all uneven strains that might otherwise be caused by any unequal yielding of the ingots.

The press is worked by direct high-pressure pumps at about 3 tons per square inch. The gradual increase of pressure required is regulated by a by-pass valve, the regulation being an extremely easy matter, and the power required being very small, 30 horse-power being sufficient for an 8,000-ton press dealing with a cast of 60 tons of steel.

This process is already quite beyond the experimental stage, as it has been in constant daily use in Messrs. Jessop's works in Sheffield for over two years in the manufacture of their highest qualities of crucible steel. The press they use (Fig. 4) is of 1,100 tons' power, and the sizes of ingots made at a cast, and the time occupied in compressing, are as follows:

```
        One ingot of 34 cwt........  ...............45 minutes
        Two ingots of 17 cwt., placed tandem........35    ”
  or,   Six ingots of 8½ cwt., ranged two abreast.....25    ”
```

Up to the present upwards of 1,500 ingots have been dealt with in this press, and not a single failure has been experienced. Fig. 3 is a photograph of sections of a compressed and of a non-compressed ingot, each of 17 cwts., and of the same quality of steel, having been cast simultaneously from the same ladle. The compressed ingot is entirely free from pipe, and sound right up to the top, but besides this it will be seen from the fracture that the texture is far finer, indicating the work that has been put on the steel by the compression.

It is the practice at Messrs. Jessop's works in the case of the larger sizes of ingots to keep the top open during the process of compression. This is done by laying a fireclay ring on the top of the ingot and using a feed rod. Directly the compression commences, just sufficient pressure is applied to cause the liquid metal to rise up into this ring. The level of the liquid metal is watched by the man who controls the pressure, and it indicates exactly the increase of pressure required to take up the contraction due to cooling. Towards the end of the process
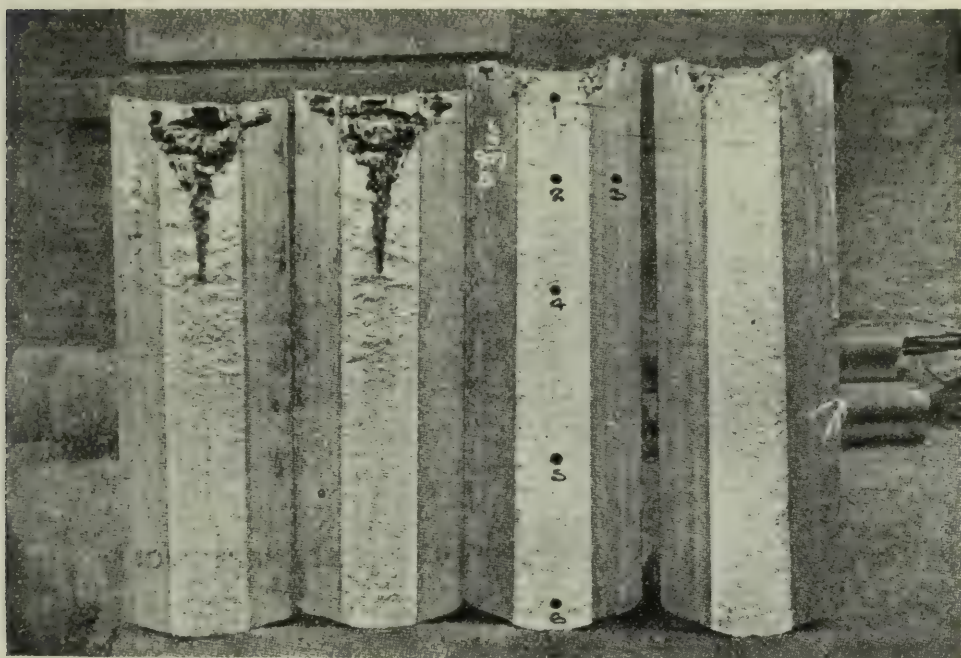
Fig. 3

the last portion of the liquated metal is squeezed out and rejected. Analysis shows that this contains about 0.05 per cent of sulphur; or about four times the average percentage in the ingot, and consequently a substantial improvement in quality is effected by this means, which is very valuable, especially in high-class steels. An ordinary pressure gauge indicates when the full pressure has been reached.

The following analysis taken from a compressed ingot, Fig. 3, shows a remarkable uniformity of composition and absence of segregation:

		Sulphur Per Cent	Phosphorus Per Cent
Drillings from hole No. 1		0.011	0.009
,, ,, ,, ,, 2		0.019	0.013
,, ,, ,, ,, 3		0.019	0.009
,, ,, ,, ,, 4		0.016	0.011
,, ,, ,, ,, 5		0.016	0.009
,, ,, ,, ,, 6		0.014	0.009
Liquated portion squeezed out		0.052	0.027

Other analyses given in appendix show equal uniformity of composition, and this was the invariable experience.

The best proof of the success of this process is the fact that the waste amounts to barely 5 per cent, that is to say, practically the whole of the ingots are used, and stand, without any instances of failure, the very severe tests of finishing and hardening to which crucible steel is subjected in making milling cutters and other similar tools.

With open-hearth steel equally satisfactory results have been obtained, and Messrs. Jessop are now putting down a 7,200-ton press for this class of steel, and for dealing with larger ingots up to 20 tons in weight.

To summarize, the advantages obtained by the use of this system are briefly as follows:

Firstly, an absolutely sound ingot is insured free from any pipe or cavity, so that the whole of the ingot can be used, and practically no waste incurred.

Secondly, being able to watch the top of the ingot and get rid of the liquated portions, a great improvement in the quality of the steel can be obtained.

Thirdly, the ingots are cast in place, and have not to be moved until the completion of the compression.

Fourthly, the simplicity and cheapness of the plant, and the ease with which it can be worked by unskilled labor.
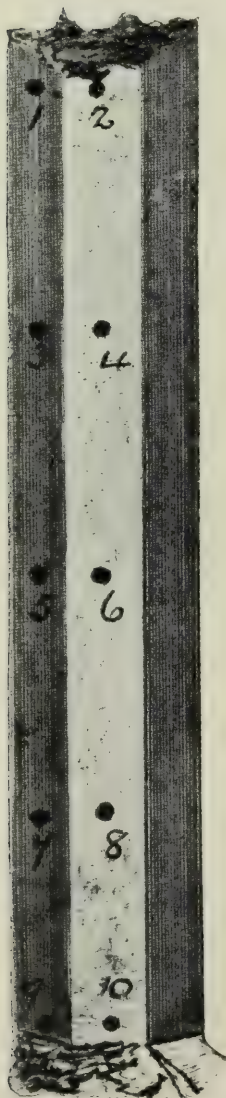
Fig. 4

Fifthly, owing to the way the molds are

divided, the ingots are made parallel, which is some facility in rolling.

The process is, of course, specially suitable for cases in which a superior quality of steel and severe tests are required, as, for instance, for tires, axles, billets for wire-drawing, and all other purposes in which the absolute soundness of the steel and freedom from blowholes and all defects is of great importance. Besides this, advantage may be taken of the fact that the compressed ingot is at least equal to steel that has been forged or cogged, and consequently the cost of the subsequent processes of manufacture may in many cases be greatly reduced by the adoption of this system.

APPENDIX

ANALYSIS OF DRILLING 6-100 C

No.	Sulphur Per Cent	Phosphorus Per Cent
1	0.022	0.012
2	0.024	0.015
3	0.019	0.013
4	0.019	0.011
5	0.016	0.013
6	0.016	0.009
7	0.016	0 012
8	0.014	0.009
9	0.014	0.010
10	0.011	0.011

ANALYSIS OF DRILLING 6-102 C

No.	Sulphur Per Cent	Phosphorus Per Cent
1	0.014	0.014
2	0.036	0.024
3	0.016	0.011
4	0.016	0.013
5	0.014	0.010
6	0.011	0.008
7	0.014	0.010
8	0.011	0.008
9	0.011	0.012
10	0.011	0.011

PRELIMINARY NOTE ON THE INFLUENCE OF MANGANESE ON IRON *

By J. O. ARNOLD and F. K. KNOWLES

Respectively Professor and Demonstrator of Metallurgy in the University of Sheffield

NOTWITHSTANDING the supreme importance of the element manganese in iron and steel metallurgy, it is a curious scientific fact that the exact influence of nearly pure metallic manganese alloyed in varying proportions with nearly pure metallic iron is still unknown to steel metallurgists. In February, 1888, Mr. Hadfield read before the Institution of Civil Engineers his classic paper describing the discovery of what is now generally known as manganese steel. Mr. Hadfield's alloys ranged in essential composition as follows:

	Per Cent
Carbon	from 0.2 to 2.1
Manganese	,, 0.83 ,, 21.69
Silicon	,, 0.03 ,, 0.84

Comparatively recently Dr. Léon Guillet published mechanical tests made on "a series of manganese steels containing little carbon." The composition of Dr. Guillet's alloys is given as follows:

	Per Cent
Carbon	from 0.034 to 0.396
Manganese	,, 0.432 ,, 33.480
Silicon	,, 0.163 ,, 1.362

These steels are designated "*aciers bruts de forge,*" but no information as to method of manufacture, size of ingots or forging details are given. In making his deductions, Dr. Guillet ignored the influence of the abnormally high silicon present, and, independently of this point, the chemical and mechanical correlation of at least two of his alloys appears to be inaccurate. His alloy No. 2 contained:

	Per Cent
Carbon	0.273
Manganese	1.296
Silicon	0.320

* Iron and Steel Institute, May, 1906, meeting.

The above steel registered the following mechanical test:

Maximum Stress Tons per Square Inch	Elongation Per Cent on 8 Inches	Reduction of Area Per Cent
27.0	24.5	73.4

The correlation of the chemical and mechanical properties of a similar steel was published by one of the authors at the Institution of Civil Engineers in December, 1888, and is as follows:

	Per Cent
Carbon	0.28
Manganese	1.25
Silicon	0.07

Maximum Stress Tons per Square Inch	Elongation Per Cent on 2 Inches	Reduction of Area Per Cent
37	26	47

Dr. Guillet publishes another discrepancy in connection with his alloy No. 5, the composition of which is given as follows:

	Per Cent
Carbon	0.058
Manganese	4.200
Silicon	0.304

The above alloy gave the following mechanical results:

Maximum Stress Tons per Square Inch	Elongation Per Cent on 8 Inches	Reduction of Area Per Cent
27.7	21.5	76.5

Mr. Hadfield, in his original paper already quoted, describes a steel containing

	Per Cent
Carbon	0.40
Manganese	3.89
Silicon	0.09

The above steel gave the following mechanical figures:

Maximum Stress Tons per Square Inch	Elongation Per Cent on 8 Inches	Reduction of Area Per Cent
38.0	0.5	0.0

The discrepancy between Mr. Hadfield's result and his own is attributed by Dr. Guillet to the fact that his (Dr. Guillet's)

steel was very low in carbon. A test obtained by the authors, however, confirms Mr. Hadfield's conclusion as to the brittleness of both iron and steel containing about 4 per cent of manganese, and suggests that Dr. Guillet may inadvertently have substituted a very mild ordinary steel for the alloy containing 4 per cent of manganese. The accuracy of this suggestion is, as a matter of fact, proved by Dr. Guillet's own micrograph, Fig. 1, in his memoir. This exhibits crystals of ferrite mixed with a few dark pearlite areas.

The authors' check alloy contains:

	Per Cent
Carbon	0.050
Manganese	3.728
Silicon	0.050

The above alloy, when rolled and normalized, registered the following mechanical test:

Maximum Stress Tons per Square Inch	Elongation Per Cent on 2 Inches	Reduction of Area Per Cent
57.8	1.0	1.7

Method of Preparing Alloys of Nearly Pure Iron and Manganese

The difficulties of preparing practically pure iron and manganese alloys are well known. One of them has been removed by the production of nearly carbon-free manganese by the "Thermit" process of Dr. Goldschmidt. Another difficulty has been well described by Hadfield in the following words: "For the ordinary crucible process, if plumbago pots are used, too much carbon is taken up and ordinary Sheffield white crucibles are eaten through."

The authors are pleased to announce to the Institute that the above difficulties have recently been practically overcome in the crucible steel laboratory at the Sheffield University, and series of alloys ranging in manganese from about 0.3 to 35 per cent. The maximum percentages of carbon * and silicon are present in the 35 per cent alloy, being respectively about 0.1 and 0.2 per cent. The relatively high proportion of silicon is unavoidably due to the fact that the metallic manganese used,

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* It is absolutely necessary to determine the carbon in these alloys by combustion, as the color test may give hopelessly low results.

although the purest obtainable, nevertheless itself contained no less than 0.72 per cent of silicon. It may be here remarked that the alloys containing from about 20 to 35 per cent of manganese have a distinctly brassy appearance, both in the polished bars and in the fractures.

The details of manufacture are as follows:

Swedish bar, containing 99.8 per cent of iron, was made fluid in the special " one cross " crucible, manufactured for the last sixteen years by the authors for melting steel for research purposes. This " pot " is made from the following mixture:

	Per Cent
Unburnt Stourbridge fireclay	45
Unburnt Derby fireclay	21
Unburnt Stannington fireclay	21
Unburnt Cornish china clay	10
Low sulphur coke dust	3

The above mixture, in which the proportions of Cornish clay and coke dust form an irreducible minimum, must be trodden for five instead of three hours, or the pots will probably collapse in use. Even with this extra treading the crucibles are soft and difficult to handle, and in this connection the authors have to acknowledge the great skill with which their crucible steel melter, Mr. W. Stacey, has carried out almost unreasonable instructions. The metallic manganese was in each case separately melted in a special crucible made from the following mixture:

Crystalline magnesia fused in electric furnace	15 lbs.
Unburnt Stourbridge fireclay	12 oz.
Water containing by volume $12\frac{1}{2}$ per cent of fluid silicate of soda	650 cc.

As the above crucible had to be closely fitted into a protective ordinary plumbago crucible, the proportions of the above mixture are important, especially as regards the silicate of soda, because it is obvious that the coefficient of expansion of the outer and inner crucibles must be nearly identical, otherwise the inner magnesia crucible may burst the outer plumbago pot, with disastrous results.

It is of great importance that the nearly pure iron and manganese should be completely fluid at almost the same moment. The total period of melting averages five and a half hours, and the manganese should be charged about four and

a half hours after the iron. If the iron, after clear melting, has to wait for the manganese, it will begin to oxidize, cut through the white pot, and automatically teem itself into the cellar. In this connection it is of considerable metallurgical interest to record that such overmelted iron contains about 0.2 per cent of oxygen, and it is hopeless to attempt to forge it. The red-shortness produced by dissolved ferrous oxide is well exemplified in Fig. 1, which reproduces a photograph of the end of the cogged bar from an ingot of nearly pure iron kept in the furnace for about twenty minutes after clear melting. These data should be of interest to makers of iron and steel lumps.

To return to the author's series of alloys. The crucibles containing the molten iron and manganese were withdrawn
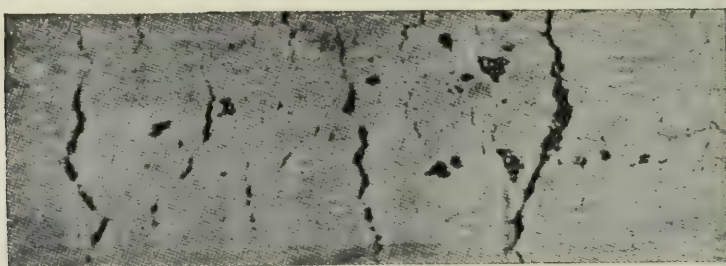

FIG. 1

from the furnace, their contents mixed, half a minute allowed for transfusion, and the alloys were then cast into 2-inch square ingots, weighing about 35 lbs. each. These ingots were cogged down under the hammer to $1\frac{1}{2}$-inch square, bolted in the rolls to $1\frac{1}{4}$-inch square with rounded corners, and, finally, rolled to 15-16 inch round. The bars were not reeled.

The mill observations were as follows: In cogging, the ingots stiffened with increased manganese contents and from about 13 to 20 per cent worked like ordinary tool steels, whilst from 20 to 35 per cent the alloys behaved like hard tungsten steels. All the ingots were quite free from red-shortness. In rolling, nothing special was noticed below 13 per cent of manganese, when the alloys stiffened up to 20 per cent, and from this point to 36 per cent rolled like " special hard " steels.

The finished bars, each about 12 feet long, were examined for liquation by taking drillings from the middle and each end,

when the somewhat disconcerting fact was discovered that most remarkable liquations had taken place. In this respect the authors' experience is not similar to that of Mr. Hadfield, who found a maximum difference of only about 0.5 per cent of manganese in various parts of his ingots. The following table shows the results registered in three typical alloys made by the authors:

Experimental Ingot No.	MANGANESE PER CENT IN ROLLED BARS		
	One End	Middle	Other End
977	3.07	3.48	3.42
944	16.60	13.85	11.96
966	26.53	28.24	35.14

Unfortunately the authors are unable to state which of the above percentages are associated with the tops and bottoms of the respective ingots. The above data of course necessitate, in connection with the research to which the present paper is only preliminary, an enormous and unexpected amount of work, since each test piece used must be separately assayed for manganese at the exact point of fracture. Moreover, as the complete research will deal with the chemical, thermal, microscopical, mechanical, electric and magnetic characteristics of all the alloys in their normal, quenched and annealed conditions, some hundreds of extra manganese assays will have to be made. On the other hand, the twenty-three bars under examination will yield a range of percentage which could only be obtained in ordinary circumstances from a series of, say, 200 ingots. When the research is completed it is possible, but hardly probable, that some of these costly alloys may prove of practical importance. It is, however, certain that theoretically, in connection with the fundamental physics of steel, the data will be of supreme importance, and the authors respectfully suggest that, pending the publication of the completed and correlated observations, it would be well for theorists, in their own interests, to suspend judgment on the nature of alloys which have now been prepared for the first time in the history of metallurgy.

USE OF OXYGEN IN REMOVING BLAST-FURNACE OBSTRUCTIONS *

By the Chevalier C. DE SCHWARZ (Liége)

ALL experienced blast-furnace engineers are acquainted with the great inconvenience, anxiety and even, in certain circumstances, danger caused by the tap hole of a blast furnace becoming closed up by solid iron, so that it cannot be opened by means of the ordinary appliances without a certain lapse of time. There is the danger of the liquid iron accumulating on the hearth of the blast furnace and reaching the slag and the blast tuyères, thus causing serious disturbances and sometimes explosions. It often becomes necessary to make a new tap hole higher up, and to reduce or to stop the blast temporarily, which may result in the formation of scaffolds or other serious inconveniences well known to blast-furnace engineers.

The case is still more serious if the blast tuyères of the furnace get closed up by solid iron, either partially or entirely, owing to a scaffold dropping suddenly, or from other causes. Should it in such a case be impossible to get a hole through the iron blocking up the tuyères within a certain time, a new temporary tuyère, at a higher level, must be applied, and even this remedy often does not have the desired effect. There are, in fact, few cases in metallurgical practice where quick and effective measures are of greater importance and more imminently necessary than those mentioned above.

Hitherto the opening of tap holes closed up by solid iron has usually been effected by forcing a hole through the iron by means of a steel bar driven by hand hammers. If hand methods do not suffice, a heavy " ram," suspended on chains and worked by a dozen men, is employed. However, it sometimes happens that the steel bar snaps off, leaving the broken end in the hole already made, or that the liquid iron cools down in coming out, and solidifies in front of the tap hole, thus making matters worse than they were before.

Coke and heated blast, as well as petroleum, are sometimes employed for opening a closed up tap hole or tuyère, but these require too long a time to take effect, and, in the case of a

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* The Iron and Steel Institute, May, 1906, meeting.

tuyère, the latter is, as a rule, utterly destroyed by the operation. A strong electric current of from 400 to 1,000 ampères has also been used for opening tap holes, but this method is similarly open to the objection that it does not work quickly enough, besides which it is very expensive.

The application of compressed oxygen in such cases has completely overcome all these difficulties, as a closed tap hole or tuyère can be opened in a few minutes only, besides which the method has the merit of being exceedingly simple and cheap, as will be seen from the following description:

The iron to be burned through (pierced) is first heated from outside, at the spot selected for making the hole, by means of an oxy-hydrogen flame, which up to now has proved to be the most useful for the purpose. It can, however, be replaced by any other combustible gas in case of necessity.

The hydrogen and the oxygen gases are compressed into two separate steel flasks, each flask being provided with a suitable outlet valve, in order to regulate the pressure and the quantity of the escaping gas according to requirement. The " burner " consists of an outer and an inner tube, the outer tube supplying the hydrogen, and the inner tube the oxygen. This simple appliance is worked as follows:

The hydrogen is allowed to escape first, and is lighted, after which the stream of oxygen is turned on. The pressure of both gases is first kept low, but gradually raised and regulated in such a way as to give a very hot flame, which heats the spot upon which it impinges to a white heat. The pressure of the oxygen is then raised to such an extent that the iron commences to burn, which is shown by sparks being thrown about.

The pressure of the oxygen is now further raised to 30 atmospheres and above, whilst the supply of hydrogen is entirely stopped. It is now the iron alone which burns, thus replacing the hydrogen as a combustible, whereby, as shown hereafter, a degree of heat is developed which far surpasses that produced by means of oxy-hydrogen gas. The high pressure of the escaping oxygen, at the same time, serves to force out all the molten iron, thus keeping the hole burnt through perfectly clean throughout the operation. It can be shown that a solid block of cold iron or steel, say 16 inches thick, can in this way be pierced within one or two minutes.

The heating effect of the oxy-hydrogen flame alone is far too low to serve the purpose of opening closed up tap holes or tuyères. This is principally due to the fact that (on account of the comparatively great volume taken up by hydrogen) the loss of heat through derivation is much too large, as compared with iron, taking both, as in our case, as combustible matters into account.

On burning 1 kilogram of hydrogen (with oxygen) 13,057 calories are produced, whilst when burning iron (with oxygen) only 748 calories are generated. However, 1 kilogram of hydrogen occupies 87,234 times as much space as 1 kilogram of iron. Therefore, a certain volume of iron, when burning with oxygen, produces about 5,000 times as much heat as an equal volume of hydrogen in equal circumstances:

$$\left(87,234 \; \frac{748}{13,057} = 5,012\right)$$

When iron burns in oxygen the heat evolved is concentrated on a comparatively very small area. This explains the enormously high temperature produced, and the quick action, as mentioned before, notwithstanding that, at the same time, a considerable amount of cold is produced owing to the expansion of the compressed oxygen after leaving the steel flask. This shows itself at the tube leading the oxygen from the flask to the " burner," which becomes coated with ice, the temperature of the tube being only about 14° F. The process, above described, yields remarkable results when employed for opening a blast or slag tuyère blocked up by iron, because the great heat produced when iron burns with oxygen might lead to the conclusion that the tuyère in question must be melted away, taking the thinness of metal in a tuyère into consideration. This, however, is not the case. Experience has shown that, for instance, a slag tuyère of only $1\frac{3}{8}$-inch inner diameter can be thoroughly cleaned from all the iron adhering to it without being injured in any way. The tuyère does not get heated at all, but cools down, considering that the temperature of the oxygen, coming from the tube, is, as already stated, reduced below freezing point owing to expansion.

The oxygen process has been successfully applied for opening tap holes of open-hearth furnaces where they have become

blocked up with iron or steel. It is of great importance that no delay should occur in tapping an open-hearth furnace as soon as the liquid metal has reached the desired degree of decarbonization, as otherwise its composition might change, owing to the delay, to such an extent as to render it useless for the desired purpose.

The new process overcomes difficulties of this nature in a few minutes.

Experiments are also being made as to the employment of the new process for improving steel ingots by removing the " pipe " caused in the upper portion owing to shrinkage during cooling. The crust of solid steel or iron above the pipe is burnt through in the way already described, within less than a minute, and superheated liquid metal of the same quality as the rest of the ingot poured in. This thoroughly fills up the pipe. The experiments are not completed as yet, but the results so far obtained seem to promise final success.

The oxygen process has also been successfully employed in removing deadheads or runners on steel castings. This is of special value in cases where the hardness of the steel casting is such as to resist the action of cutting the tool at the place where the deadhead or runner is joined to the casting.

In rolling-mills, where interruptions of work are very costly, the oxygen process can be advantageously employed in melting through and quickly removing any broken shaft or axletree from couplings, flywheels, etc., instead of causing long delay and expense in doing this work by means of chisels and drills.

The oxygen process has also been successfully employed for piercing armor plates for warships and armored turrets. This is of special importance in case such plates are of hard metal. A hole through such a plate of, say, 9-inch thickness, would require two or three hours if drilled in the ordinary way, whilst with compressed oxygen this work can be done within fifteen to twenty seconds. This remark applies also to the manufacture of hollowed weldless steel goods, either pressed or cast, especially if hard steel is used where the driving in of a treblet might spoil the article in question.

Whilst, as already mentioned, oxy-hydrogen has proved the most convenient for producing the necessary initial heat, before applying the oxygen gas alone, in order to open blocked

up tap holes or tuyères in furnaces, the electric current has proved more convenient for the same purpose if armor plates, steel castings, etc., are to be pierced. A current of from 4 to 6 volts and 200 to 220 ampères is quite sufficient to produce the necessary initial heat before applying the oxygen.

The oxygen process above described was invented and first practically applied by Dr. E. Menne, engineer to the Cologne Müsener Bergwerks Aktien Verein at Creuzthal in Westphalia. Some improvements have been effected and carried into practical operation by the Société Anonyme Oxyhydrique Internationale at Brussels for cutting boiler plates, tubes, etc., so quickly and accurately that the oxygen process has secured favor as a trustworthy method for this purpose. The arrangement consists essentially of two tubes which can be placed one behind the other, the first tube supplying oxy-hydrogen gas, and the second oxygen gas. The oxy-hydrogen heats the plate up to a white heat, and the compressed oxygen burns (cuts) the plate exactly as desired. The apparatus for guiding the two tubes works in such an easy and exact manner that the slightest pressure of the finger-tips suffices to guide it as desired.

Finally, it may also be permissible to take the financial outlook of the oxygen process into consideration. The principal outlay is that for the oxygen gas, which, at present, costs about 3 s. for 1,000 cubic feet; but a reduction in this price is expected.

For opening a blocked up tap hole or a tuyère, as a rule, not more than 8 or 10 cubic feet of oxygen are required; in exceptional cases, however, from 20 to 40 cubic feet of oxygen gas are necessary.

The apparatus itself is very simple and inexpensive. It consists of two steel flasks, each with a reducing valve, and of a few yards of iron tubes and armored hose. Several blast-furnace works in England, Germany, Austria, France and Belgium have already adopted the process, with satisfactory results.

ABSTRACTS *

THE Hardness of the Constituents of Iron and Steel. H. C. Boynton. Abstract of report on research work, as holder of Andrew Carnegie research scholarship, presented at the May, 1906, meeting of the Iron and Steel Institute. — The substance of this report may be briefly reviewed as follows:

(1) Former methods for the determination of the hardness of the constituents of iron and steel were very rough and only relative, and could not be made quantitatively in microsections.

(2) After careful research Jaggar's microsclerometer, invented for the determination of the hardness of minerals, seemed applicable to polished specimens of iron and steel.

(3) Jaggar's work has shown that a diversity of methods has been employed by scientists of all countries to determine hardness quantitatively, and after due consideration of all this work he came to the decision, accepting the definition of Dana that "hardness is the resistance offered by a smooth surface to abrasion," that the boring method, using a diamond point as the abrader, would produce the most uniform results.

(4) By stating precisely that the quality which he intended to measure was the resistance which a smooth surface offers to abrasion, Jaggar proceeded to construct an instrument, built like a watch, attachable to the foot of a microscope and admitting of very delicate adjustments and manipulation, so that small areas in mineral sections could be tested quantitatively.

The principle of his instrument is the measurement of the number of revolutions of a tetrahedral diamond point under (*a*) a uniform speed of rotation, (*b*) constant weight and (*c*) drilling to a constant depth.

(5) After some experiments, the author found that the microsclerometer was applicable to the determination of the hardness of iron and steel constituents by slightly varying the method of procedure, but without changing in any way the principles involved.

(6) Summarizing the results obtained and presenting them in round numbers, and reducing to a common unit the hardness of pure ferrite, the figures may be presented as in the following table:

AVERAGE HARDNESS OF ALL THE CONSTITUENTS OF IRON AND STEEL

Constituent	Present, in	Average Hardness	Ratio
Ferrite....	Electrolytic iron..........	460	1
,, ...	,, ,, quenched.	990	2.15
,, ...	Average of all unhardened samples................	610	1.03
,, ...	Commercial wrought irons.	686–1,643	1.5–3.6
Pearlite...	Series 0.13–1.52 per cent carbon................	842–4,711	1.8–10.3
,, ...	Series 0.35–0.86 per cent carbon................	1,745–2,150	3.8–4.2
Sorbite....	0.48 and 0.58 per cent carbon steel..............	2,400–24,650	5.2–53.6
Troostite..	Steel, 0.58 per cent carbon..	40,564	88.2
Martensite	Series 0.20–1.52 per cent carbon................	17,896–120,330	38.9–261.6
Austenite..	White cast iron (3.24 per cent carbon)..........	47,590	103.4
Cementite.	White cast iron (3.24 per cent carbon)..........	125,480	272.8

(7) The comparative figures and results of all the tests can be most advantageously reviewed by reference to the tables and diagrams accompanying this report.

The report consists of 47 typewritten quarto pages, with 5 diagrams and 2 photomicrographs. **No. 495.**

On the Methods of Testing the Protective Power of Paints Used on Metallic Structures. E. Ebert, International Association for Testing Materials. Paper to be read at the Brussels Congress, September, 1906. 2,200 w. — A short criticism of the

usual methods of testing protective paints. The author con-
cludes that " the durability of the anti-rust preparation depends
upon the quality of the linseed oil employed, and that for decid-
ing the quality of the linseed oil it is very desirable that we
should be in possession of some process which will enable us to
ascertain quickly, simply and reliably what its quality is, even
when already mixed with pigments. **No. 496. B.**

**Report on the Progress of Metallography since the Congress
at Budapest, 1901.** F. Osmond and G. Cartaud, International
Association for Testing Materials. Paper to be read at the
Brussels Congress, September, 1906. 17,000 w., illustrated. —
The authors give brief outlines of recent progress in metallog-
raphy, including the technology of the subject, equilibrium
curves, effects of thermal and mechanical treatments, etc. **No.
497. B.**

Progress in the Electric Smelting of Iron and Steel (Die
Weitere Entwicklung der Elektrischen Verfahren zur Herstel-
lung von Eisen und Stahl). Albert Neuburger. Glaser's Annalen,
March 15, 1906. 5,500 w. — The author describes recent electric
furnaces for the smelting of iron and steel, including those of
Kjellin, Schneider and Gin. **No. 498. D.**

Technical Progress in Blast-Furnace Practice (Technische
Fortschritte im Hochofenwesen). Oskar Simmersbach. " Stahl
und Eisen," March 1, 1906. 3,000 w. (To be continued.) — The
author describes the briquetting of iron ores and the conveying
appliances of blast-furnace plants. **No. 499. D.**

On Methods for Testing Pipes. Prof. M. Gary, International
Association for Testing Materials. Paper to be read at Brussels
Congress, September, 1906. 7,000 w., illustrated. — This is the
report of the committee appointed to study the " Introduction
of Uniform Testing Methods for Pipes." **No. 500. B.**

The Effect of Copper in Steel. F. H. Wigham.   Paper
presented at the May, 1906, meeting of the Iron and Steel Insti-
tute. 5,000 w. — The author describes some experiments under-
taken to ascertain the effect of copper on the properties of steel.
His conclusions are as follows:
" (1) Copper is very difficult to alloy with steel so as to

obtain a homogeneous mass containing over 2 per cent, even with the addition of aluminum.

"(2) Steel alloyed with copper in the pure form with the addition of aluminum is not so perfectly mixed as it is when it is added to the charge of steel in the furnace, and more copper could safely be employed provided it was in the metal before it was completely converted into steel.

"(3) In steel containing 0.5 per cent or more of carbon it is not of practical value to use more than 0.6 per cent of copper.

"(4) The steel with 0.25 per cent of copper and alloys up to 0.25 per cent of copper with high carbon (say, of 0.70 per cent) give, with or without a high percentage of manganese, a good quality of wire.

"In conclusion, it may be considered as proved that copper to the extent of 0.25 per cent is no disadvantage in the manufacture of the best classes of steel wire." **No. 501. B.**

Chain-Making Machinery. Emile LeLong. Paper presented at the May, 1906, meeting of the Iron and Steel Institute. 3,500 w., illustrated. — The author describes briefly the usual methods of chain manufacture and the LeLong machine which is considered an improvement on the other methods. **No. 502. B.**

Influence of Silicon, Phosphorus, Manganese and Aluminum on Chill in Cast Iron. E. Adamson. Paper presented at the May, 1906, meeting of the Iron and Steel Institute. 10,000 w., illustrated. — **No. 503. B.**

Solid Rolled Steel Car Wheels and Tires. Peter Eyermann. 14,000 w., illustrated. Paper read at the May, 1906, meeting of the Iron and Steel Institute. — The author describes the different methods employed in the production of solid rolled steel car wheels and tires. **No. 504. B.**

METALLURGICAL NOTES AND COMMENTS

Eber B. Ward   The following biographical sketch of Eber B. Ward (see frontispiece) is extracted from a recent article in "The Munsey," by Herbert N. Casson:

" The first capitalist to appreciate the Bessemer process was Capt. Eber B. Ward. This extraordinary man, whose life was a crescendo of self help, may be called the pathfinder of the American steel trade. He made the first commercial Bessemer steel at his Detroit plant in 1864, and in the following year he produced the first steel rails in America at his rolling mill in Chicago. Ward was the son of a poor lighthouse keeper. When he was nine years of age his mother died and he was set to work as cabin boy in a shabby little schooner. By the time he was full grown he knew everything about a ship from keel to flag and had bought a small vessel of his own. For years he continued to buy ships or build them, until he became the steamship king of the Great Lakes. Then, in middle life, he suddenly flung aside his prestige, sold most of his fleet, built furnaces and rolling mills and became the first of steel kings.

" No sooner had Ward begun to make and sell Bessemer steel than he found himself plunged into a patent war. He had bought the Kelly and Mushet patents, but the complete Bessemer process was threefold. It involved, first, the use of air as fuel, originated by Kelly; second, the addition of a carbon mixture, originated by Mushet; and, third, the use of a tilting converter and casting ladle, originated by Bessemer. Ward had two thirds of the patents, and was opposed by Alexander L. Holley, who had bought the Bessemer rights. Neither could make steel satisfactorily without infringing on the legal rights of the other. Each man had his partners. With Ward were Zoheth S. Durfee, of New Bedford, and Daniel J. Morrell, of Johnstown. With Holley were John F. Winslow and John A. Griswold, of Troy.

" Here we tilt against one of the most puzzling mysteries in the story of steel. Ward and Durfee were both shrewd, self-made, aggressive, wealthy men. They possessed a two-thirds control of a process which has since that time produced more

than three billion dollars' worth of steel. The Kelly patent, which they owned completely, did not expire until 1878. It was not likely that the American courts would uphold the claims of Bessemer. Kelly had already beaten him in the Patent Office, and did so again in 1871. Yet at the close of a year's wrangling and legal cannonading, the Ward forces suddenly flew the white flag and surrendered all their patents to Holley in return for a 30 per cent interest in the consolidation. It was apparently a case of the dog swallowing the alligator.

" To account for the fact that Ward allowed the scepter of the steel empire to be snatched from his hand, the only reasons that the Detroit men can suggest are these:

" ' First, the heavy expense and partial failure of his Detroit steel plant. It is known that a few years afterwards he was nearly a million dollars in debt, with payment overdue and no ready money available.

" ' Second, the fact that about this time he became influenced and even guided in his business affairs by spiritualistic mediums.'

" Mr. Swank suggests that Ward and his partners were obliged to sell out for the reason that the Troy capitalists controlled the Bessemer machinery, without which the Kelly and Mushet patents were of little value. But this explanation does not clear up the mystery. It was the only instance in his long career in which Ward made such a disastrous bargain.

" By a master effort Ward overcame his monetary difficulties, and when he died of apoplexy, in 1875, his estate was valued at $5,335,000. But he had years before lost his chance of being the czar of steel. He was a man of strange extremes — self-controlled and passionate, shrewd and credulous, persistent and changeable. President Grant wished him to become Secretary of the Treasury, but Ward found it impossible to disentangle himself from his business affairs."

Fourth Annual Report of the United States Steel Corporation.* — The fourth annual report of the United States Steel Corporation, signed by Elbert H. Gary as chairman of the board of directors and by William E. Corey as president, was made public on March 16. It covers the operations of the corporation for the year ended December 31, 1905.

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* The " Bulletin," American Iron and Steel Association, April 1, 1906.

The gross sales and earnings of the corporation in 1905 amounted to $585,331,736.20, and the manufacturing and producing cost and operating expenses, including approximately $24,000,000 for ordinary maintenance and repairs, to $440,013,-432.40, leaving a balance of $145,318,303.80. To this balance should be added $2,758,633.56 received from sundry manufacturing gains and rentals, making a total net manufacturing, producing and operating income for the year of $148,076,937.36. In addition $3,298,500.12 was derived during 1905 from properties owned by the corporation, but whose earnings are not included above, and from interest and dividends on investments and deposits, making a total income from all sources of $151,-375,437.48. From this total general expenses amounting to $18,570,374.49, interest charges of $6,710,214.73, and profits earned by subsidiary companies of the corporation on sales made and not turned over to the corporation, amounting to $6,307,-189.83, should be deducted, leaving $119,787,658.43 as the net earnings of the corporation for the calendar year 1905.

The monthly earnings of the subsidiary companies of the corporation from 1902 to 1905 were as follows. Cents are omitted:

Months	1902	1903	1904	1905
January.....	$8,901,016	$7,425,775	$2,868,213	$6,810,847
February....	7,678,583	7,730,361	4,540,673	6,629,463
March.......	10,135,858	9,912,571	6,036,346	9,585,586
April........	12,320,766	10,905,204	6,863,833	9,037,925
May.........	13,120,930	12,744,324	6,256,519	10,602,187
June........	12,220,362	12,992,780	6,370,374	10,665,004
July........	12,041,914	12,384,647	6,344,771	9,035,168
August......	12,972,729	10,918,174	6,202,958	10,986,901
September...	11,930,847	9,120,134	6,226,204	11,218,513
October.....	12,652,707	7,675,141	7,250,204	12,400,307
November...	10,686,906	4,069,901	7,117,417	11,827,215
December....	8,646,146	3,292,140	7,099,010	10,988,542
Total......	$133,308,764	$109,171,152	$73,176,522	$119,787,658

While the earnings in 1905 show a gratifying increase over the earnings in 1904 and 1903 they were $13,521,106 less than the earnings in 1902.

The average number of employees of the corporation in the service of all companies during 1905 as compared with 1904 was

as follows: Manufacturing properties, 130,614, against 110,864; coal and coke properties, 20,883, against 15,654; iron ore mining properties, 12,068, against 8,477; transportation properties, 14,524, against 10,595; and miscellaneous properties, 2,069, against 1,753; total, 180,158, against 147,343. The total annual salaries and wages paid to employees in 1905 amounted to $128,052,955, against $99,778,276 in 1904.

At the end of 1905 there was again offered to the employees of the corporation and of the subsidiary companies the privilege of subscribing for preferred stock on substantially the same conditions as offered in previous years, except that the price fixed was $100 per share. Under this offer subscriptions were received from 12,256 employees, for a total of 23,989 shares.

The report says that "the improvement in the iron and steel business which became evident in the latter part of 1904, and to which reference was made in the last annual report, was generally maintained throughout the entire year of 1905. The unfilled orders on the books on December 31, 1905, amounted to 7,605,086 tons of all kinds of manufactured products, in comparison with 4,696,203 tons at the close of 1904.

" The manufacturing departments of the subsidiary companies were operated throughout the year with little interruption. The production of pig iron, steel ingots and finished products for sale exceeded that of any previous year. The production of finished products for sale, practically all of which tonnage was shipped to customers, exceeded by 1,029,154 tons the output in 1902, which was the highest production in any previous year. The average prices received in 1905 for most of the tonnage were, however, somewhat less than the prices which obtained in 1902. The volume of production in the iron ore, coal and coke departments, and the traffic handled by the transportation lines, exceeded materially all previous records.

" Satisfactory results have been obtained in the export trade. During the year there were exported 953,858 tons of manufactured products. The prices received for exports during the year were materially in excess of those previously received and approached more closely domestic prices. It is the policy of manufacturers to keep the furnaces, mills and transportation companies in operation to their full capacity whenever practicable. Obviously this is wise. It results in lower cost of pro-

duction, and, therefore, influences lower prices generally to the domestic purchaser; and it secures continuous employment to the wage earner. For these reasons it is sometimes deemed proper and desirable to sell for export what would otherwise be surplus products at prices lower than domestic prices. If a contrary policy should be adopted the general cost of production would be increased, the employees would at times be idle, and balances of trade between foreign countries and this country would be changed to the prejudice of the latter. This policy has been adopted and is practiced generally throughout the business world. However, trade conditions during 1905 enabled manufacturers of steel in this country to realize fair prices for their exported commodities.

" As in previous years liberal outlays were made by the subsidiary companies for additional property acquired, new construction, improvements and unusual replacement. The expenditures during the year for all these purposes equaled $37,890,548.74. The subsidiary companies have authorized extensive appropriations for construction and improvement work for the year 1906.

" Although the capacity of the producing furnaces and mills located at Chicago and vicinity has been materially increased from time to time, it has not kept pace with the increased, and rapidly increasing, consumption tributary to this location; and therefore a large percentage of this tonnage is now supplied from Eastern mills. In consequence of these conditions it has been decided to construct and put into operation a new plant to be located on the south shore of Lake Michigan, in Calumet township, Lake county, Ind., and a large acreage of land has been purchased for that purpose. It is proposed to construct a plant of the most modern standard, and to completely equip the same for the manufacture of pig iron, Bessemer and open-hearth steel, and a great variety of finished steel products. The total cost will be large. Notwithstanding the large sums which have been paid since the organization of the corporation for increasing the producing capacity by subsidiary companies they have only maintained their position in the trade. In 1901 these companies produced 43.2 per cent of the pig iron manufactured in this country, and in 1905 they produced 44.2 per cent. In 1901 these companies produced 66.2 per cent of the Bessemer and

open-hearth steel ingots, and in 1905 they produced 60.2 per cent.

" The organizations at the present time of this corporation and of the subsidiary companies are exceptionally good. Their efficiency is evidenced by the fact that they have utilized the well equipped plants under their management so as to re-establish in 1905 the rate of wages to the vast army of laborers on practically the same basis which existed in 1901, notwithstanding the prices received for the commodities produced and sold were materially less in 1905 than they were in 1901."

The American Iron Trade in 1905.* — The year 1905 was not only the most productive and the most prosperous year in the history of the American iron trade, but it was the most uniformly prosperous year. From January to December the demand for all leading forms of iron and steel and for the raw materials of their manufacture was continuous and persistent. There was no " dull season," no overloading of the markets, no slump in prices. Upon the other hand there was no great scarcity of iron and steel at any time, the markets in the main were well supplied, and consequently there were no " famine " prices. The orders that were sent abroad entirely lacked sensational features, because we had the capacity to meet our own wants for pig iron and finished iron and steel. Nor was our export trade neglected, as will presently be seen. Production was abnormally and phenomenally great, but best of all prices were wisely kept within reasonable bounds. We have heard of no complaints that prices were too high. There were, of course, fluctuations in prices, as is always the case in years of prosperity or years of dull trade, but in 1905 such decline in prices as took place was caused mainly by the naturally lessened activity of the summer months. This decline affected only a few products.

The increase in the production of iron and steel in 1905 as compared with 1904 was simply marvelous. Pig iron jumped from 16,497,033 tons in 1904 to 22,992,380 tons in 1905; Bessemer steel from 7,859,140 tons in 1904 to 10,941,375 tons in 1905; open-hearth steel from 5,908,166 tons in 1904 to 8,971,376

* From the annual report of the American Iron and Steel Association now in course of preparation, " The Bulletin," April 1, 1906.

tons in 1905; and all kinds of rails from 2,284,711 tons in 1904 to 3,373,929 tons in 1905. The total production of steel in 1904 was 13,859,887 tons, but in 1905 it exceeded 20,000,000 tons. The total shipments of iron ore from the Lake Superior region increased from 21,822,839 tons in 1904 to 34,353,456 tons in 1905. It is freely predicted that even the above extraordinary figures of production in 1905 may be exceeded in 1906. The present outlook certainly justifies this opinion. The country is steadily increasing its capacity to meet any possible demand that may exist for either pig iron or manufactured iron and steel. There were no strikes or lockouts in the iron trade in 1905 that are worthy of mention.

The prices of iron and steel which prevailed in 1905 were not only kept within reasonable bounds, as above stated, but the advances that occurred over the exceedingly low prices of 1904 were really smaller than the extraordinary demand would have justified, while the forbearance of the steel rail manufacturers in keeping the price of rails all through 1905 at the same figure that prevailed all through 1904 is worthy of special mention. The railroads were helped greatly by this low price, $28, but if the critics of the so-called trusts in the iron trade could have had their way and suppressed all of them the price would have probably soared 50 per cent higher, at least for a short time.

The extraordinary demand for iron and steel in 1905 was primarily due to the continued prosperity of the country, notwithstanding the reaction of the stock market in 1903 and 1904, which unfavorably affected all business. The reaction having spent its force in the summer of 1904 the pendulum swung in the opposite direction in the last quarter of that year and in 1905. With re-established confidence in the business world, good crops, an abundance of good money, continued tariff protection against foreign competition, a large increase in our population and the steadily increasing use of iron and steel for engineering purposes and in the construction of buildings and railway cars, the great demand for iron and steel in 1905 was naturally to be expected, and it was encouraged and promoted by the good sense of the manufacturers in keeping down prices.

As in other years the railroads were the best customers of our iron and steel manufacturers in 1905. Their increased pros-

perity in that year, in harmony with that of the country generally, called for larger expenditures for rails, cars, locomotives, bridges, etc., than in 1904. There was, in 1905, an increase in the mileage of new railroad track and the betterment of track already built, and in the same year more cars and locomotives were built in this country than in any former year. The Baldwin Locomotive Works built 2,250 locomotives in 1905, but in 1904 they built only 1,453. Thus far in 1906 there has been no abatement of the demand for railway equipment.

One of the interesting features of the iron trade of this country in 1905 was the great increase that took place in that year in our exports of iron and steel, notwithstanding the active home demand for these products. In 1904, when this demand was far from being satisfactory to our manufacturers, when prices were low, and customers, whether at home or abroad, were badly wanted and diligently sought for, we exported iron and steel products of the value of $128,455,613, greatly exceeding the exports of any previous year, but in 1905 we exported iron and steel products valued at $142,928,513, an increase over 1904 of $14,472,900. Much of this increase was due to the systematic activity of the United States Steel Corporation in pushing its wares into foreign markets. Our imports of iron and steel in 1905 also showed an increase over 1904, amounting in 1905 to $26,392,728, against $21,621,970 in 1904. All the increase in exports in 1905 over 1904, and probably more than this, was caused in part by the expansion of our own iron and steel industries in that year, making necessary an increased importation of spiegeleisen, ferromanganese and other so-called raw materials, and, in part, by large importations of pig iron itself to be exported in finished forms with the benefit of the tariff drawback.

On the Manufacture of a High-class Steel from Phosphoric Irons.* — In view of the high price of superior hematite, or low-phosphorus irons, and the ores from which they are made, also that nearly all such ores are imported from abroad, and that the Swedish supply will probably be curtailed, or, at all events, increased in price by the proposed tax on exported irons and ore, it seems somewhat strange that so few attempts have been

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* William Galbraith in " The Iron and Coal Trades Review," March 23, 1906.

made by some modification of the basic process to manufacture a high carbon and high-class steel from our own ores.

Undoubtedly a " fillip " has been given to the question recently, and quite a large quantity of steel is being dealt with in the Sheffield and Midland districts made from common irons; but that steel made from superior English hematite or Swedish irons can, and is, bringing a higher price than ever, is evident from the increasing production of such steel in these districts, and the attempts to make it from common iron have not yet met with the success expected. It has not been always recognized by steel experts and chemists (the unscientific steel manufacturer always did recognize it) that it is quite possible to get a steel with a good analysis, with low phosphorus and sulphur and everything else in its favor, and yet the steel to be anything but satisfactory, and the explanation given is often " that you cannot make a silk purse from a sow's ear."

There is a big jump, however, between the basic steel process in the earlier days and that employed by the best makers now, and its progress only justifies one in believing that it can be made to do better and make steel of the character referred to regularly and consistently.

So far, it has, I think, been proved that the addition of solid carbon does not produce the carbon nor the regularity of the carbon content desired, and also, unfortunately, the basic slag has not that deoxidizing influence that an acid or siliceous slag has.

As far back as 1890, in a paper read before the Iron and Steel Institute, I showed that for these reasons it was advisable to separate the steel from the basic slag, and finish it in presence of an acid slag. It was proposed to do this simply in a ladle, as being cheaper than a furnace. The advantages of this were soon recognized on the Continent, and supplementary furnaces were used under other patents. If the metal is kept molten in presence of an acid or siliceous slag, the carbon content will be regular and the oxides present slagged off, and conditions as nearly as possible those of the crucible process will be obtained.

The presence or absence of oxides in steel is very important in deciding the quality of steel, these being probably the elements which prevent the silk purse being made. Take, as an

illustration, the manufacture of a high-class crucible steel, such as that of Huntsman. Such a steel is thoroughly homogeneous, and contains from 0.15 per cent to 0.18 per cent of manganese. We know well that such a steel would not work if produced in a Siemens furnace or a Bessemer converter, and, what is more, only very skilled melters can make it.

In the one case there is a prolonged heating, the coke being well round the crucible, in a non-oxidizing atmosphere in presence of an acid slag, and in the other cases the oxidizing influences are very apparent. If, therefore, the dephosphorized steel is kept for a short time in a Siemens furnace, under those conditions and without the addition of ore, the conditions of crucible practice are nearly fulfilled.

Another point which has retarded the progress of the basic process in this country is the expense and difficulty of getting a good low silicon pig iron, I know, of course, that in saying that I am on debatable ground, but I also know that there is considerable divergence of opinion as to what is a suitable basic pig, and that the blast-furnace man and the steel man do not agree on this point. I am perfectly safe, however, in saying that the large American furnaces, designed specially to produce such an iron cheaply, have not made a better iron, and that in this respect we are not improving. Perhaps I am not the only one who, in the earlier days of the basic process, advocated the carrying out of the desiliconizing and dephosphorizing in two separate operations, which has so many advantages that it is by no means clear that the basic Bessemer steel makers would not have been wise to have erected their plant with that object in view. It liberates the blast furnace from a very serious difficulty, it enormously reduces the wear and tear of the basic lining, and lessens the loss, and these are very serious items in either the Bessemer or Siemens basic process; the present system has only been tolerated in the hope of getting better iron. The difficulty has, of course, been met somewhat by the more modern mixer. To make the class of steel mentioned, however, or to make alloyed steel, we do not require large plants producing thousands of tons per week, but smaller units in which greater care is taken, and which can be multiplied as desired.

Such an unit producing, say, 300 tons per week might consist of two small acid-lined converters, two small basic converters

and a small (say, 12-ton) Siemens furnace. The molten metal from the cupola is blown for a short time, reducing the silicon, say, from 2 per cent to 0.3 per cent, or 0.2 per cent and the carbon, perhaps, to 2 per cent or 2½ per cent.

This metal is now blown in the basic-lined converter — a modification of a Bessemer converter.

The charge may consist in each case of 2 or 3 tons. It is apparent that the basic-lining loss is reduced to a minimum and that the phosphorus can be brought lower than when silicon is present. The slag, too, is of much more value. A slag containing, say, 14 per cent phosphoric acid may be absolutely worthless, while one containing over 20 per cent would be valuable. A phosphide of iron is on the market, and is used for the very purpose of enriching and increasing the amount of basic slag. After dephosphorizing, the molten steel is transferred to a small Siemens furnace, as explained above, in presence of an acid slag. These operations are repeated until the Siemens furnace is full, and when the necessary carbides and alloys are added the metal is tapped into the ladle as usual. Of course it is clear that scrap can be used, and it and the alloys may be added in portions at each successive addition of molten metal; a charge from the Siemens furnace can thus be got every three hours. Practically, the Siemens furnace is used simply as a receiver or mixer, and its cost will compare with that instead of with the usual method of working a Siemens furnace. A tilting furnace is clearly the best style of furnace — its advantages are apparent.

The objection to this on the score of complication will disappear on further consideration, because it really lies in the transference of the molten metal from one place to another. But this " ladling," where gravity cannot be utilized, is the modern system of dealing with steel, and is not expensive. Whatever may be the objection to the Bertrand-Thiel process, I have never heard that with its two, three or four furnaces feeding one, it was considered complicated.

The four small vessels will, with their accessories, cost about the same as the Siemens furnace, while the output is trebled, and there are the advantages of using an ordinary gray, and, therefore, a cheaper, iron, and of making superior steel, and if the steel is superior there is a big enough market, and a good enough price for it.

The Schwartz Steel Process.* — A new process of steel manufacture has been evolved by E. H. Schwartz, Chicago, inventor of the Schwartz melting and refining furnace manufactured by the Hawley-Down Draft Furnace Company of that city. In the refining process a Schwartz furnace is used with oil as the fuel. Steel is successfully made by this process in a 90-inch furnace of this type having a capacity of 6,000 pounds at the foundry of the Otis Elevator Company, Chicago. For melting a portion of the metal to be refined a cupola is used, although a part of the heat is raised to the melting point in the furnace. The cupola is charged with one ton of low phosphorus pig iron containing about 1 per cent of silicon and 2,300 pounds of return melt steel scrap. While this charge is being raised to the proper temperature 800 pounds of return melt steel scrap and 2,400 pounds of low phosphorus pig iron are being heated to about the melting point in the furnace. The cupola charge when melted is poured into the Schwartz furnace, and on account of the large amount of steel scrap, it is claimed that the entire carbon content is below 2 per cent, and is further reduced to 0.25 per cent in approximately two and a half hours by the oxidizing flame in the furnace. The metal is superheated by burning the carbonic oxide liberated during the refining process, and the high heat necessary to burn this gas is obtained from two converging blow-pipe tuyères located near the top of the furnace. The flame enters the furnace in two converging jets, passes down on the metal bath, makes two revolving turns and then passes out the spout. The inventor states that a temperature of over 4000° F. is obtained in the furnace, and that a perfect oxidizing flame can be controlled by the ½-inch needle point valve located at the side of the furnace.

After the heat has been applied to the entire furnace charge for one and one-half hours tests are made, and fifteen minutes before pouring ferrosilicon and ferromanganese are added. Aluminum in quantities of 2½ pounds per ton of steel is placed in the ladle before the heat is poured. While the pig iron and steel scrap are being melted in the cupola, sulphur and phosphorus are absorbed from the coke, but the total furnace charge is lowered as the initial charge in this vessel shows no increase of either sulphur or phosphorus owing to the use of fuel oil. Extensive

* "The Iron Age," April 26, 1906.

tests have been made that show no increase of either sulphur or phosphorus from the oil. The pig iron and scrap are gradually charged into the cupola, and as a blast pressure of only 9 ounces is maintained, oxidation is reduced to a minimum. Approximately 4 tons of steel can be made by this process in four hours, and castings ranging from 2 ounces to 2,500 pounds can be poured. Eighty gallons of oil for a ton of steel are consumed and the cupola melt ratio is about 1 to 6. By the use of two Schwartz furnaces a cupola will not be required, and the inventor claims that a high grade of acid steel can be made. Steel is also made by this process in a plant installed at West Drayton, England.

It is further claimed that malleable iron can be made by the use of this furnace and a cupola. In this case 60 per cent of the charge is to consist of return melt scrap with a mixture of steel scrap, as desired, and this is melted in a cupola with a low blast pressure and sufficient coke. The remaining 40 per cent of the charge is melted in the furnace and consists of pig iron, either malleable Bessemer or charcoal. The cupola charge is poured into the furnace when the latter has reached the melting point, and the steel charge is melted for about one-half hour. If necessary, ferrosilicon can be added to the metal to secure the proper silicon content. It is claimed for this process that a greater amount of scrap can be used than is used either by air furnaces or in open-hearth practice.

Air Furnace Bottoms in Malleable Practice.*— At the instance of a malleable foundry where considerable difficulty was experienced in keeping the " bottom " of an air furnace in good shape, an inquiry was sent around to those malleable foundries which were known to have the furnaces. Twenty replies were received, and an interesting summary thus obtained. In order to make the information particularly valuable, there was requested the size of the heats, the number of heats made with the same bottom, the material used for the bottom and the particulars about bottoms " coming up."

Practically all the foundries use some form of fire sand for making bottom, that is to say, a sand the silica content of which runs up very high, say over 95 per cent. Furthermore

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* Richard Moldenke in " The Iron Trade Review," April 5, 1906.

the fluxing impurities, such as lime, alkalies and oxide of iron, must be very low, but yet enough to just bake the sand together, or " set " it when properly fired. The method of making bottom seems to be about like this: The sand is spread on in layers of 1 inch or more, and fired to set it. This takes about fifteen minutes. About 5 inches are put on in this way, the process being similar to that made use of in the open-hearth furnace. In the latter case, with careful patching after each heat, a bottom should last up to 1,000 heats. In the case of the air furnace some founders preferred to take off only three heats before renewing bottom, but in each case stated that they could take off more without risk, if they chose. Other founders got from 6 to 12 heats off their bottom, and these figures seemed to cover the majority of replies. The two exceptions were as follows: The first, with a natural draft air furnace, gave an efficiency of 30 heats from the same bottom. The second case, with a production of 29 heats of 14 tons, these bottoms were made by mixing ground fire brick with the fire sand.

While the method of making bottom as above described was the usual one, there were some slight variations. Thus, several foundries made the 5-inch bottom all at once. One founder uses a top dressing of core sand one-half inch thick. Another uses salt or fireclay, or both, in his firesand. Several add ground firebrick. All concur in emphasizing the necessity of thoroughly drying out each layer before the next is put on, and especially the junction between the old and the new sand on the bottom. In case the furnace foundation should draw dampness, it is advisable to erect a concrete box for the base, and fill in with broken firebrick before building up the furnace.

The word " firesand " is used advisedly, for it covers a number of appellations. Thus " silica sand " is much used, though sand itself is silica of variable purity; then " steel sand," " glass sand," lake sand, etc., all coming under the general head of a sand which is refractory to a high degree.

Finally the size of the heats as given by the replies to the circular inquiry are between 7 and 18 tons, which would show the general practice in this respect. The further conclusion derived from this attempt to get first-hand information, about a phase of foundry practice, is that more than enough in the way of a valuable return is gotten for the little trouble it took on the

part of the individual foundrymen who replied, and who now have the opportunity to compare their practice with the general average.

Henry Cort.* — A memorial tablet of Henry Cort, one of Lancashire's numerous and distinguished inventors, was this week presented to the authorities of the Manchester University by Mr. J. P. Bedson. The tablet, which will find a place in the Metallurgical Department, is a cast of the original bronze tablets unveiled recently in Hampstead and Lancaster parish churches, the gift of Mr. Charles H. Morgan, the American engineer. Cort's life and work are indicated briefly on the tablet in the words: " In memory of Henry Cort, born at Lancaster, 1740, interred at Hampstead, 1800, to whom the world is indebted for the arts of refining iron by puddling with mineral coal and of rolling metals in grooved rolls." The vice-chancellor of the university (Dr. Hopkinson, K.C.) presided at the ceremony, and the gift was received by Mr. Alderman Joseph Thompson on behalf of the authorities. There was a large company assembled in the Schunck Laboratory on the occasion.

Mr. Bedson, in his address, spoke of Cort as a Lancashire worthy who made a lasting impression, not upon only the iron industry of this country, but of the whole world, even up to to-day. " Do we not ride," he said, " in trams upon rails which are only possible through Cort's invention of grooved rolls? " He quoted from an account in an encyclopedia a hundred years after Cort's inventions, in which it was said: " The amount added by his inventions to the national wealth since the commencement of the present (nineteenth) century is estimated at £600,000,000, while they have given employment to 6,000,000 persons." Mr. Bedson said this was borne out by the fact that in 1882 Great Britain made 2,800,000 tons of puddled iron, while the whole make of the world was 8,750,000 tons, puddled and rolled by Cort's inventions. Of Cort's financial and personal misfortunes Mr. Bedson also gave a sketch, and declared that he did not think such a memorial could find a more fitting place than in the metallurgical laboratory of the university in the industrial center of Cort's native county.

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* " Iron and Steel Trades Journal and Colliery Engineer," February 10, 1906.

Sir William H. Bailey, who was afterwards called upon for an address, said he could hardly account for the neglect there had been in perpetuating the name and fame of a man like Cort, who had been nearly forgotten among the illustrious inventors of Lancashire. He was no doubt a Dutch refugee. He came at the beginning of our commercial supremacy, and we were supreme yet, notwithstanding what was said. Sir William recalled some of the names of Lancashire men whose inventions were now in the workshops of the world, and said that if Cort had been born in France or Germany there would have been monuments to him all over the country. He suggested that when the new Free Library was built in Manchester it should contain a hall of fame like that of Munich, in which the memory of such benefactors would be kept alive.

Afterwards a vote of thanks was passed to Sir William Bailey for his address, on the motion of Professor Dixon, seconded by Dr. Bone and supported by Professor Armstrong, a visitor.

Iron and Steel in India.* — It is now several months since the Indian Railway Board decided to encourage the construction of wagon frames and bodies in that country for a period of three years. For this purpose tenders are to be invited in India for one fourth of the total stock required, and iron and steel of Indian manufacture are to be used whenever possible. This fact is recalled to mind by the experience recorded by the Bengal Iron and Steel Works in the past year. It appears that although the company's production of pig iron and castings was larger than in the preceding twelve months, the steel department has proved unsatisfactory, and will probably be closed in about two months from the present time. The disappointing results in the steel department, the directors state, have been brought about mainly by the inefficiency of the European workmen who were sent out to India. The men were replaced, and the working of the furnaces improved, but the subsequent failure of both of the steel furnaces within a short time of each other brought matters to a crisis. The furnaces have been repaired so as to enable the existing raw materials to be worked up, and at the end of two months further operations at the steel works will be abandoned, at any rate for the time being. This regrettable result, while

* " The Mechanical World," March 23, 1906.

being disadvantageous to the company as stopping its produc-
tion of steel, will also not advance the interests of those engin-
eering firms in India who have secured the concession in regard
to one fourth of any new stock of wagon frames and bodies
required by the State Railway Board in the ensuing three years.
It is probable that many years will pass away before the Indian
iron and steel industry will become of considerable importance,
notwithstanding the new works which are projected at the
present time.

German Basic Steel in England.* — Some discussion has
gone on in foreign technical journals relative to German basic
steel. A British monthly, " Vulcan " refers to the fracture of
an Austrian steam boiler under hydraulic test, the plates being
of German steel made from phosphoric pig; there has been some
criticism also of some axles from German works furnished to the
Metropolitan District Railway, London. In quoting the follow-
ing from the journal mentioned attention may be called to the
fact that similar criticisms have been passed on other steels
imported into England; also that basic open-hearth steel as well
as basic Bessemer once fell under attack, but now takes the
place to which chemical and physical tests entitle it:

" Phosphoric ores on the continent have largely determined
the employment there of basic methods of making and the gen-
eral use of basic steel. The advocates of this material shelter
themselves behind the results of tensile and bending tests of
strips cut from this plate; but experience has shown repeatedly
that high tenacity and elongation may be obtained from strips
cut from a plate alongside a fracture which has failed under
normal working load, and in fact this peculiarity of basic steel
is its most dangerous feature and the one which English engin-
eers hold in dread. It is, in fact, corroborated by tests of
strips cut from the fractured plate in the boiler under notice,
which gave a tenacity in two cases of 28.2 and 29.2 tons per
square inch and 24.6 and 22.5 per cent of elongation on 8 inches."

The London " Times Engineering Supplement " makes this
additional comment on the matter: " It is stated that efforts
are being made by German steel makers to introduce their basic
steel plates to the notice of English boiler makers, and that the

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* " The Iron Age," April 5, 1906.

low price at which these are offered is a strong temptation to some of the smaller firms engaged in this business, especially when accompanied with guarantees of tensile and elongation tests. It would seem that the interests of the buyer in a matter of this description are even more important when concerned with a steam boiler, liable to explosion, than in other relations of the Merchandise Marks Acts, and, consequently, that the derivation and nature of the material of such boilers, supposing any be made for sale of these plates, ought to be clearly and prominently indicated on their exteriors."

A Casting Process for Armor Plate.* — Reference is made in Sheffield, England, correspondence of the London "Ironmonger" to the experiments carried on by the Hadfield Steel Foundry Company, Limited, in that city, in the casting of light armor plates, the process dispensing with forging or rolling. Patents covering the method have been taken out by R. A. Hadfield. It is stated that "the metal is cast in a mold so formed as to produce a plate with a face having ridges and channels or corrugations. After pouring and while the casting is hot it is removed to a furnace to cool down slowly to prevent internal strains. Then the sand is removed and the casting carefully cleaned. It is next put into a furnace and upon the corrugated surface charcoal is placed to a thickness of several inches. The furnace is raised to a high temperature — between 900 and 1100° C. — and the plate is allowed to remain there for several days; it is then permitted gradually to cool. The plate is reheated and cooled four or five times with a gradual reduction of the temperature to which it is reheated, and at the final heating is dipped or sprayed with oil or water, according to the hardness required, so that the corrugated face, being hotter than the back, will become hard, while the back remains soft and tough."

A Large Steel Ingot.† — At the Manchester Works, Openshaw, of Armstrong, Whitworth & Co., the largest steel ingot that has ever been made was cast this week. It weighed not less than 120 tons. The ingot was cast on the well-known Whitworth system of fluid pressure; that is, the 120 tons of molten

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* "The Iron Age," April 26, 1906.

† "Iron and Steel Trades Journal and Colliery Engineer," February 10, 1906.

steel was poured out from the melting furnaces into a huge steel ingot mold box, this box itself weighing 180 tons. On the mold box being filled with molten steel, the whole is then pushed under a monster hydraulic press having a ram 6 feet in diameter with a working pressure of 3 tons per square inch. This press is, therefore, capable of exerting a total actual pressure of 12,000 tons. The huge ingot referred to was, whilst in a molten condition, subjected to this enormous pressure of 12,000 tons, the action of this process being to make the ingot homogeneous and sound throughout, and free from those cracks and fissures which are so detrimental to steel ingots. The ingot just cast is for the manufacture of the huge low-pressure turbine rotors for the 70,000 horse-power Cunard turbine liners.

The Iron and Steel Institute. — The annual meeting of the Iron and Steel Institute was held in London on the 10th and 11th of May, 1906. The Bessemer gold medal for 1906 was presented to Mr. Floris Osmond and awards of the Andrew Carnegie gold medal and research scholarship for 1906 were announced. The following papers were presented:

FLORIS OSMOND

(1) " The Influence of Silicon, Phosphorus, Manganese and Aluminum on Chill in Cast Iron," by E. Adamson (West Hartlepool).

(2) " The Influence of Manganese on Iron," by Prof. J. O. Arnold (Sheffield).

(3) " The Relation between Type of Fracture and Microstructure of Steel Test Pieces," by C. O. Bannister, Assoc.R.S.M. (London).

(4) " Compression of Steel Ingots in the Mold," by A. J. Capron, M.Inst.Mech.E. (Sheffield).

(5) " The Manufacture of Rolled Solid Steel Car Wheels and Tires," by P. Eyermann (Wisconsin).

(6) " Brittleness in Thin Steel Sheets," by E. F. Law, Assoc. R.S.M. (London).

(7) " Chainmaking Machinery," by E. Lelong (Couillet, Belgium).

(8) " The Use of Oxygen in Removing Blast-Furnace Obstructions," by C. de Schwarz (Liége).

(9) " Volume and Temperature Changes Occurring during the Cooling of Cast Iron," by Prof. Thomas Turner, M.Sc., Assoc. R.S.M. (Birmingham).

(10) " The Influence of Copper in Steel," by F. H. Wigham (Wakefield).

The following reports on work carried out during the past year by holders of Carnegie research scholarships were submitted:

(*a*) " Hardness of the Constituents of Iron and Steel," by Henry C. Boynton, D.Sc. (Cambridge, U. S. A.).

(*b*) " Heat Treatment of Wire," by J. Dixon Brunton (Musselburgh).

(*c*) " Quarternary Steels," by L. Guillet, D.Sc. (Paris).

(*d*) " Influence of Carbon on Cast Iron," by W. H. Hatfield (Sheffield).

(*e*) " The Preparation of Carbon-Free Ferromanganese," by E. G. Ll. Roberts and E. A. Wraight, Assoc.R.S.M., (London).

(*f*) " Deformation and Fracture in Iron and Steel," by Walter Rosenhain, B.A., B.C.E. (Birmingham).

The annual dinner of the Institute was postponed until July 27, 1906.

The secretary has issued the following circular under date of April 10, 1906.

" In accordance with previous announcements, arrangements have been made to hold a joint meeting of members of the American Institute of Mining Engineers and of the Iron and Steel Institute in London, during the week commencing July 23, 1906.

" The Lord Mayor of London has kindly consented to act as chairman of the London Reception Committee, and a varied program of entertainments, visits and excursions will be provided. Meetings for the reading and discussion of papers will be held on the mornings of July 24, 25 and 26, with visits to works in the afternoons. The Lord Mayor will give an evening

reception at the Mansion House on July 24. On July 25 there will be an entertainment in the evening at the Earl's Court Exhibition, and on July 26 at the Crystal Palace. On July 27 the annual dinner of the Institute, to which the American visitors are invited, will be held, by kind permission of the city corporation, at the Guildhall. On July 28 a visit will be arranged to the blast furnaces of Messrs. Butlin & Co., at Wellingborough. Detailed particulars will be issued when the arrangements are further matured. In order to make adequate arrangements it is necessary to have early information as to the number of members likely to attend the meeting. Will you, therefore, have the kindness to fill up the annexed preliminary reply and return it to me at your earliest possible convenience.

" After the meeting in London, a tour will be arranged for the American visitors to York, Middlesbrough, Newcastle-on-Tyne, Glasgow and Edinburgh. As an alternative excursion a number of the American visitors have been invited by the local reception committee for the summer meeting of the Institution of Mechanical Engineers to take part in the Cardiff meeting of that society."

American Society for Testing Materials. — The following is extracted from a recent circular issued by the secretary of the American Society for Testing Materials: " The ninth annual meeting of the society will be held at Atlantic City, N. J., on Thursday, Friday and Saturday, June 21–23, 1906. The headquarters will be at the Hotel Chalfonte.

" The following nominations were reported for the ensuing term (1906–8):

" For President, Charles B. Dudley; for Vice-president, Robert W. Lesley; for Secretary-Treasurer, Edgar Marburg; for member of Executive Committee, James Christie.

" That the remarkable growth of the society within recent years has been well sustained is apparent from the fact that no less than 171 applications for membership have been received since the last annual meeting. Deducting losses by death, resignations and arrears in dues, the net gain is 131, the total membership being now 808. With a little individual effort on the part of the membership at large this number should be largely increased before the meeting."

REVIEW OF THE IRON AND STEEL MARKET

The most important market event in the iron trade in May was the opening of order books by the northern rail mills for orders for 1907 delivery about the first of the month. The western roads bought heavily, and within three weeks the Chicago mill was practically sold up for the entire year. The demands of western roads have increased rapidly of late, and western rail-making capacity is entirely inadequate. It is a curious spectacle that the Illinois Steel Company should be sold up for the year 1907 while the Carnegie Steel Company is still able to sell for 1906 delivery.

Demand for other finished steel products has been rather quiet, but there has been a fair run of business which, supplemented by the unfilled orders with which the month was entered, has kept mills in operation at full capacity, and the prospects are that production can be continued at full capacity for several months, with merely a continuance of the present buying. In some lines the pressure for deliveries is light, but in other lines it is heavier, so that the entire pig iron and steel output is well absorbed in one direction or another. In plates, for instance, the mills have only a few weeks' full operation ahead, while in others, such as rails and shapes, they are booked up solidly for months to come.

About the middle of May pig tin broke all records in the London and New York markets, selling at close to 50 cents a pound. It has since reacted, but is still very high. Effective May 18 the American Sheet and Tin Plate Company advanced tin plates 15 cents a box to $3.75 on account of the advance in tin.

The course of the iron market for the balance of the year depends almost entirely on crop and financial conditions. With good crops and no financial troubles a continuance of the present heavy production is certain, with heavy buying in the fall laying a substantial foundation for 1907.

Pig Iron. — The feature of the market has been the scarcity which developed in steel-making pig for delivery to July 1, foundry and forge being in light demand and somewhat easier in

price. Sales of both Bessemer and basic have been made for deliveries in the second half, establishing prices at about the same basis as for second quarter deliveries and settling for the time a point which was much in doubt. The United States Steel Corporation bought about 20,000 tons of Bessemer, with seller's privilege of giving a little basic, from the Bessemer Furnace Association for May delivery at $17.25, valley, for the Bessemer and 25 cents less for the basic. The Jones and Laughlin Steel Company bought 20,000 tons of Bessemer from the Association for May and June delivery, 6,000 from an independent interest for prompt delivery and the entire make of the Sharpsville Furnace Company's furnace for six months beginning when the furnace is blown in, sometime in June, probably from 30,000 to 40,000 tons, all at about $17.25, valley furnace. The Republic Iron and Steel Company took 20,000 tons of Bessemer from the Association for June and July delivery, and later another 10,000 tons for July delivery at the same price. Round purchases of basic were made by the Inland Steel Company and Grand Crossing Track Company, Chicago, and the United Steel Company at Canton, Ohio, for third quarter delivery, at $16.75 to $17, valley furnace. Furnaces are behind on deliveries of basic for second quarter to some steel interests, and have made efforts to buy from other producers, bidding $16.75 at furnace. Foundry iron has declined. On analysis, silicon 1.50 to 2 per cent, foundry iron has sold at $16, valley, for early delivery, and it is believed that on a round tonnage for extended delivery, $16.25, furnace, would be done on regular No. 2 graded by fracture. The foundries are all holding off, but a number will have to make purchases for third quarter during June, and there may be a buying movement which will advance foundry iron and put it more in line with Bessemer. But for the scarcity of steel-making pig Bessemer would have declined ere this. Forge has been quiet and is a trifle lower. In quotations below, the lower prices are for second half delivery and the higher prices for small lots for early shipment: F. o. b. valley furnace: Bessemer, $17.25 to $17.50; basic, $17; No. 2 foundry, $16.25 to $16.75; forge, $15.65 to $15.75. Delivered Pittsburg: Bessemer, $18.10 to $18.35; basic, $17.85; No. 2 foundry, $17.10 to $17.60; gray forge, $16.50 to $16.60. Delivered Chicago: Northern No. 2 foundry, $18.50 to $18.75; malleable Bessemer, $18.30 to

$18.80; Lake Superior charcoal, $19 to $19.50. Delivered Philadelphia: No. 2 X foundry, $18.50 to $18.75; standard gray forge, $16.50 to $16.75. F. o. b. Birmingham: No. 2 foundry, $14; gray forge, $12.50. Freight: Valleys to Pittsburg and Cleveland, 85 cents; to Chicago, $2.30; Birmingham to Cincinnati, $3; to Chicago, $3.90; to Pittsburg, $4.60; to Philadelphia by all-rail, $4.75; to Philadelphia by rail and water, $4.75.

Ferro-Manganese. — The market is decidedly easier, contrary to expectations of sellers, and foreign 80 per cent ferromanganese is offered for second half delivery at $75. For small lots for June delivery about $10 more is asked.

Steel. — The supply of billets has greatly improved and prices are about a dollar a ton lower. Sheet bars continue very scarce. The Carnegie Steel Company has put the entire capacity of the Youngstown mill on rails, cutting off the proportion of billets this plant has recently been making, while it has made up for this at the expense of sheet bars by putting the Mingo plant exclusively on regular and small billets. We quote billets a dollar a ton lower and not very strong at the new prices of $26 for Bessemer and $27 for open-hearth, f. o. b. Pittsburg, while sheet bars are unchanged and firm at $28, Pittsburg, for long lengths.

Plates and Shapes. — Demand for plates has been lighter, and even the large mills can now make deliveries on new business in a couple of weeks. They are well filled on universal mill plates. Very narrow sheared plates are being shaded in some cases $1 to $2 per ton. The regular price on plates remains at 1.60 cents for tank quality. Shape business has been lighter, the mills being entirely filled up through the summer, and some important projects are being deferred until next year. As expected by the better posted in the trade, no structural business has come from San Francisco as yet. Shape prices remain on the basis of 1.70 cents, Pittsburg, for beams and channels, 15-inch and under, angles and zees.

Merchant Bars. — Following the concession of 10 cents a hundred made to the agricultural implement makers on steel bars, some other large consumers have been insisting on a concession, but the mills adhere steadfastly to the regular price of 1.50 cents, f. o. b. Pittsburg, half extras, on Bessemer and open-

hearth bars. At a meeting held in Pittsburg May 22, this price was reaffirmed. Iron bars are weaker, and at Pittsburg prices are a dollar lower, while in the eastern market there are more sellers at the price quoted in this report a month ago. Prices are now 1.55 cents, delivered Pittsburg, and on the basis of 1.50 cents, f. o. b. Pittsburg in both eastern and western markets, equal to 1.63½ cents delivered Philadelphia and 1.66½ cents delivered Chicago.

Sheets and Tin Plates. — As noted, tin plates were advanced 15 cents a box on May 18 to $3.75 f. o. b. mill, Pittsburg district, for 100 pound cokes. There is not much business, as mills are sold for months ahead at considerably lower prices. Some of these contracts will prove a clear loss to mills if they have to pay anything like 40 cents a pound for the tin. Sheets are very firm, and an advance from the present official prices of 2.40 cents for black and 3.45 cents for galvanized, No. 28 gauge, Pittsburg, is very probable. There has been a heavy demand from San Francisco, particularly for galvanized corrugated.

Scrap. — The market has been very low, and after a slight stiffening now seems to be on the downward grade. There is scarcely any demand for heavy melting stock, and it would not bring over $14.50 delivered Pittsburg, while for delivery at Sharon or Steubenville $15.25 might be secured on a limited tonnage. Other prices, delivered Pittsburg, are about as follows: Cast borings, $8.50; wrought turnings, $12.50; low phosphorus scrap, $19; No. 1 cast scrap, $15.25.

Connellsville Coke. — The market is easier since the settlement of the anthracite trouble. For prompt lots the market is about $2.40 for furnace and $2.70 for 72-hour foundry.

STATISTICS

Production of Iron and Steel in Canada.* — The American Iron and Steel Association has received from the manufacturers the statistics of the production of steel ingots and castings and of finished rolled iron and steel in the Dominion of Canada in 1905. It has been necessary to estimate the production of one rolling mill.

The total production of all kinds of steel ingots and castings in Canada in 1905 was much the largest in the history of the Dominion, and exceeded by 221,412 tons that of 1902, the year of next largest production, when 182,037 tons were made. As compared with 1904 the increase amounted to 254,665 tons, or over 171 per cent. Bessemer and open-hearth steel ingots and castings were made in both 1904 and 1905, the production of open-hearth steel amounting in the latter year to over 59 per cent of the total. Almost all the open-hearth steel reported in 1904 and 1905 was made by the basic process. The Bessemer steel was all made by the acid process. A few hundred tons of steel were made in 1905 by a special process. The direct steel castings made in 1905 amounted to 9,394 tons, against 6,505 tons in 1904. Our records do not show that Canada has made any crucible steel down to the close of 1905.

The following table gives the production of all kinds of steel ingots and castings in Canada from 1894 to 1905, in gross tons:

Years	Gross Tons	Years	Gross Tons	Years	Gross Tons
1894	25,685	1898	21,540	1902	182,037
1895	17,000	1899	22,000	1903	181,514
1896	16,000	1900	23,577	1904	148,784
1897	18,400	1901	26,084	1905	403,449

The production of all kinds of finished rolled iron and steel in Canada in 1905 was also much greater than in any previous year, and amounted to 385,826 tons, as compared with 180,038 tons in 1904, the year of next largest production, an increase of 205,788 tons, or over 114 per cent.

The following table gives the production of all kinds of iron and steel rolled into finished forms in Canada from 1895 to 1905, in gross tons:

* " The Bulletin," American Iron and Steel Association, May 15, 1906.

Years	Gross Tons	Years	Gross Tons	Years	Gross Tons
1895	66,402	1899	110,642	1903	129,516
1896	75,043	1900	100,690	1904	180,038
1897	77,021	1901	112,007	1905	385,826
1898	90,303	1902	161,485	....	....

The production of Bessemer and open-hearth steel rails in 1905 amounted to 178,885 gross tons, against 36,216 tons in 1904; structural shapes, 885 tons, against 447 tons in 1904; nail and spike plate, 4,110 tons, against 5,030 tons in 1904; plates and sheets, 4,944 tons, against 3,102 tons in 1904; all other finished rolled products, excluding muck and scrap bars, blooms, billets, sheet bars and other unfinished forms, but including, for 1905, 1,120 tons of forging blooms or forging billets, 197,002 tons, against 135,243 tons in 1904. The total quantity of all kinds of iron and steel rolled into finished forms in Canada in 1905, including forging blooms and forging billets, amounted to 385,826 tons, against 180,038 tons in 1904. Of the 385,826 tons of finished iron and steel reported for 1905, about 318,405 tons were rolled from steel and 67,421 tons from iron, as compared with 126,850 tons rolled from steel and 53,188 tons from iron in 1904.

In 1905 the rolling mills and steel works in Canada which operated cut nail or wire nail factories produced approximately 366,800 kegs of cut nails and wire nails, as compared with 324,000 kegs of cut nails and wire nails in 1904.

On December 31, 1905, there were 21 completed rolling mills and steel works in Canada. In addition 1 plant was being built and 2 plants were projected. Of the completed plants 3 were equipped for the manufacture of steel castings only, 1 for the manufacture of open-hearth steel ingots only, 5 for the manufacture of Bessemer or open-hearth steel ingots and rolled products and 12 for the manufacture of rolled products only. The building plant was being equipped for the manufacture of black plates and tin plates and terne plates. One of the projected plants is to be equipped for the manufacture of skelp and bar iron and the other for the manufacture of wire rods.

Of the 21 completed rolling mills and steel works in Canada on December 31, 1905, 4 were located in Nova Scotia, 5 in Quebec, 10 in Ontario, 1 in New Brunswick and 1 in Manitoba. The single building plant is in Ontario. The two projected plants are also in Ontario.

RECENT PUBLICATIONS

Metallurgical Calculations, by Joseph W. Richards, professor of metallurgy in Lehigh University. Part I: Introduction, Chemical and Thermal Principles, Problems in Combustion. 208 6 × 9-in. pages. McGraw Publishing Company. New York. 1906. Price, $2.00. — The larger part of the contents of this book has been published as a serial in the " Electrochemical and Metallurgical Industry," in 1905 and 1906. Regarding the incontestable value of Professor Richards' calculation, there is little to be added to the following extract from his preface:

" To those who are practically conversant with metallurgical operations, no argument need be offered as to the value of properly made calculations concerning the running of a process. To those who are engaged in teaching, it need only be said that if the value of metallurgical problems as a means of teaching metallurgy is doubted, try the plan and see how wonderfully it succeeds. To artisans or students working alone, it may be said that the mastery of such problems and their working principles constitutes the practical mastery of metallurgy as a science, and leads inevitably to a strong and commanding grasp of the subject.

" If ever rule-of-thumb is to be replaced in a metallurgical process by scientific operation, the change must be based on experiments, classification of results and calculations therefrom. The principles involved are physical, chemical and mechanical; the scientific metallurgist must master these, use them as tools and overcome brute nature by their skillful employment.

" Every metallurgical problem is an exercise in pure logic and mathematical reasoning; the premises are observed facts — all that can be learned of the process by direct observation and measurement; the conclusions desired are everything which can be deduced from the premises by hook or by crook, by direct logical process or by inference. In this way data and information are obtained which cannot be directly observed or measured,

and which are of the most essential value for thoroughly under-
standing the process.

"To the study of this hitherto somewhat neglected and yet
amazingly fruitful side of metallurgical work the author invites
the reader, and hopes that the work here presented may in itself
reward every one who spends time in reading and effort in master-
ing its contents."

The book is well printed on excellent paper and very satis-
factorily bound.

*Annual Report of the Smithsonian Institution, 1904, United
States National Museum.* 780 6 × 9-in. pages; illustrated.
Government Printing Office. Washington. 1906. — This an-
nual publication contains the report of the assistant secretary of
the Smithsonian Institute, Richard Rathburn, with appendices
and a number of papers describing and illustrating collections in
the United States National Museum. The latter include a
"Contribution to the History of American Geology," of 546
pages, by G. P. Merrill, head curator of geology, of very great
interest and containing excellent portraits of eighty-two dis-
tinguished American geologists.

The Elements of Physical Chemistry, by J. Livingston R.
Morgan, professor of physical chemistry, Columbia University,
Third edition, revised and enlarged. 510 4½ × 7½-in. pages.
John Wiley & Sons. New York. 1905. Price, $3.00. — The
author in his preface states that as a basis for the revision of his
work he has been so fortunate as to have a copy of the former
edition, containing suggestions and criticisms from the hand of
Professor Ostwald. In the present edition he has attempted to
bring the subject matter up to date; to distinguish sharply
between hypothesis and fact; to employ mathematics simply as
a means to an end and to make the matter as intelligible as
possible even to the non-mathematical reader. The titles of the
chapters are as follows: Introductory Remarks; The Gaseous
State; The Liquid State; The Solid State; The Phase Rule;
Solutions; Thermochemistry; Chemical Changes; Electrochem-
istry; Problems; Tables and Appendix.

Elements of Mining Geology and Metallurgy, by G. W.
Miller. 489 4 × 7½-in. pages; illustrated; flexible covers.
"The Daily Mining Record." Denver, Colo. Price, $3.50. —

This book contains in a concise and readily available form a large amount of information of importance to the mining geologist and metallurgist. Purely theoretical considerations are absent, only questions of an essentially practical character being dealt with. The twelve chapters bear the following headings: Elements of Mining Geology; Occurrence and Metallurgy of Iron; Descriptive Geology of Gold and Silver; Testing and Assaying of Gold and Silver Ores; Stamp Milling and Mill Construction; Treatment of Gold and Silver Ores by the Cyanide Process; Descriptive Geology of Copper; Assaying and Smelting of Copper; Lead-Geology, Assaying and Metallurgy; Rarer Metals and Minerals; United States Mining and Patent Laws and Glossary of Mining Terms.

That the description of processes is sometimes too brief may be shown by the five pages which the author devotes to the metallurgy of iron and in which the open-hearth process is not even mentioned, while it is stated that the average height of a blast furnace is forty-five feet. Notwithstanding these shortcomings the book is a valuable one, to be commended to metallurgists and engineers who desire to obtain information regarding elementary questions of mining geology and metallurgy in the minimum amount of time.

Eisenhüttenkunde, dritter band, Die Gewinnung des Eisens aus den Erzen. dritte Lieferung (Schluss des III Bandes), by Dr. Hermann Wedding. 300 6 × 9-in. pages; numerous plates and other illustrations. Friedrich Vieweg und Sohn. Braunschweig. 1906. — This is the third and last part of Dr. Wedding's important work dealing with the extraction of iron from its ores, and it is much to be hoped that an English translation of it will soon be published.

Transactions of the American Electrochemical Society. Volume VIII. 1905. 299 6 × 9-in. pages; illustrated. The American Electrochemical Society. Philadelphia. 1905. Price, $3.00. — The present volume consists of the proceedings of the eighth general meeting, held in Bethlehem, Pa., September 18 to 20, 1905. As a frontispiece the book contains a reproduction of a pastel portrait of Dr. Wilhelm Ostwald.

The Encyclopedia of Practical Engineering, edited by Joseph G. Horner. Volume III. Boi-Civ. 240 7½ × 9½-in.

pages; profusely illustrated. Virtue & Co. London. Price, each volume, 7s. 6d. — The first two volumes of this important encyclopedia were reviewed in the April, 1906, issue of the *Iron and Steel Magazine*. The work will be completed in ten volumes to appear at the rate of one volume every three months. It is intended to cover the entire practice of civil and mechanical engineering.

Jahrbuch der Elektrochemie. Eleventh yearly volume. Edited by Professors W. Nernst and Borchers. 937 $6\frac{1}{2} \times 9\frac{1}{2}$-in. pages; illustrated; paper covers. — The great care and thoroughness with which this valuable yearly publication is prepared is deserving of much praise. The engravers' and printers' work is also of highest grade. The indexes of authors' names and contents covers nearly one hundred pages. This volume would seem indispensable to the close student of electrochemistry.

Notes on Electrochemistry, by F. G. Wiechmann. 145 6×8-in. pages. McGraw Publishing Company. New York. 1906. Price, $2.00. — So elementary and concise a treatment of electro-chemistry should be welcomed by those desirous to acquire a fundamental knowledge of this subject without having recourse to bulky treatises. The book is divided into six chapters dealing respectively with general principles, electrical energy, electrochemistry, electrolytic dissociation, electro-analysis and electro-technology.

BOOKS RECEIVED

Lehrbuch der Chemischen Technologie der Energies, by Hanns V. Juptner. Volumes I and II. Respectively 256 and 340 6×9-in. pages; illustrated; paper covers. Franz Deuticke. Leipzig and Vienna. 1905. Price, each volume, 7 marks.

Tables for the Use of Blacksmiths and Forgers, by John Watson. 88 $4 \times 6\frac{1}{2}$-in. pages. Longmans, Green, & Co. London, New York and Bombay. 1906.

Shaft Governors, by W. Trinks and C. Housum. 97 4×6-in. pages; illustrated. D. Van Nostrand Co. New York. 1906. Price, $0.50.

The Principles and Practice of Iron and Steel Manufacture, by Walter MacFarlane. 266 $5 \times 7\frac{1}{2}$-in pages; illustrated. Longmans, Green, & Co. London, New York and Bombay. 1906. Price, 3s. 6d.

Des Ingenieurs Taschenbuch, Herausgegeben von Akademischen Verein "Hütte." Volumes I and II. Respectively 1334 and 926 $4\frac{1}{2} \times 7\frac{1}{2}$-in. pages. Wilhelm Ernst & Son. Berlin. 1905. Price, first part, 18 marks; second part, 16 marks.

PATENTS

RELATING TO THE METALLURGY OF IRON AND STEEL

UNITED STATES

816,877. HOT-BLAST FURNACE. — James M. McClave, Toronto, Ohio. Filed January 21, 1905.

817,099. METALLURGICAL FURNACE. — George H. Benjamin, New York, N. Y. Filed September 18, 1905.

817,899. PROCESS FOR PRODUCING FUEL FROM PEAT BY MEANS OF THE ELECTRIC CURRENT. — Joseph B. Bessey, London, England. Filed October 5, 1905.

818,147. APPARATUS FOR HEATING METALS. — Frederick J. Clinch-Jones, Leamington, England. Filed June 1, 1905.

818,615. BLAST - FURNACE - CHARGING APPARATUS. — John W. Dougherty, Steelton, Pa. Filed November 22, 1904.

818,684. INGOT MOLD. — Henry Grey, New York, N. Y., assignor to American Universal Mill Company, New York, N. Y., a corporation of West Virginia. Filed October 3, 1902.

818,867. PORTABLE HOT-BLAST PYROMETER. — Edward Brown, Philadelphia, Pa. The Provident Life and Trust Company of Philadelphia, Pa., administrator of said Edward Brown, deceased. Filed January 20, 1905.

818,918. PROCESS OF MANUFACTURING IRON AND ITS ALLOYS. — Marcus Ruthenburg, Lockport, N. Y. Filed November 28, 1903.

818,927. CASTING MACHINE. — Edwin E. Waite, Philadelphia, Pa., assignor to The Enterprise Manufacturing Company of Pennsylvania, Philadelphia, Pa., a corporation of Pennsylvania. Filed June 24, 1905.

819,046. MEANS FOR CONTROLLING GAS VELOCITY IN REVERBERATORY FURNACES. — Byron E. Eldred, Bronxville, N. Y., assignor to Combustion Utilities Company, New York, N. Y., a corporation of New York. Filed February 8, 1905.

GREAT BRITAIN

5,817 of 1905. REFINING IRON. — D. I. R. Simpson, Johannesburg. Refining iron, as it runs from the blast furnace, in a receptacle through which an air blast is forced.

7,251 of 1905. PUDDLING IRON. — Bayliss, Jones & Bayliss, Wolverhampton. An improvement in puddling furnaces, whereby the cast iron is preliminarily heated by the waste heat of the furnace before the puddling operation begins.

12,200 of 1905. FURNACE. — Feliner & Ziegler, Frankfort-on-the-Main. An inclined rotating furnace for agglomerating fine iron ores before smelting; the ores being fed in at the top and a spray of coal dust and fluxes at the bottom, so that at a certain point in their descent the ores become partially smelted and bound together.